CIVIL ENGINEERING

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Site of Grand Coulee Dam on the Columbia River, Washington, Looking East
Progress of Construction as of August 1934, Showing Excavation on Both Banks

Volume 4 — AMERICAN SOCIETY OF CIVIL ENGINEERS FOUNDED 1852 — Number 9

SEPTEMBER 1934

Among Our Writers

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J. C. MacDonald has served the Province of British Columbia for 15 years. Since 1926 he has been Comptroller of Water Rights advising on water works, irrigation, and power projects.

C. F. Williams, in addition to various military assignments, has served as District Engineer, St. Paul, Minn. He is now in charge of the improvement of the Columbia River, from its mouth to the mouth of the Snake.

B. E. Torpen's experience in hydro-electric design and construction includes the Cushman No. 1 Hydro-Electric Project for Tacoma, Wash., and the Bull Run Water Supply Dam for Portland, Ore.

F. A. Banks since 1906 has been with the U. S. Bureau of Reclamation. He was construction engineer on the Jackson Lake Dam, American Falls Dam, Thief Valley Dam, and Owyhee Dam.

C. A. Mockmore since 1921 has taught at Oregon State College, where he is now head of the civil engineering department. In 1932 he became a research associate at the University of Iowa.

E. W. James has been with the U. S. Bureau of Public Roads since 1910, since 1929 as Chief of the Division of Highway Transport, and since 1930 in charge of reconnaissance surveys for the Inter-American Highway.

Malcolm Elliott has been engaged on Government construction projects since 1906, and has been District Engineer in charge of river and harbor works in Alaska.

A. M. Rawn was for almost 20 years with the U. S. Bureau of Reclamation. His name is connected with the Yakima, Boise River, King Hill, and Columbia Basin projects.

Theodore Wyman, Jr., has been Assistant to the District Engineer, Kansas City, Mo., and District Engineer there, in charge of the improvement of the Missouri River and the preparation of 308 Reports for the Missouri River Basin.

Jeptha A. Wade has designed and constructed water supply and sanitary works for the British Imperial Munitions Board, the U. S. Ordnance Department, James H. Fuertes, and Nicholas S. Hill, Jr. For 5 years he was in charge of developing and purifying surface supplies for the Federal Water Service Corporation.

Kenneth W. Brown has been Sanitary Engineer for the Pacific Gas and Electric Company and, since 1927, for the California Water Service Company and Oregon-Washington Water Service Company.

Edward Hyatt has served the State of California since 1916. He was appointed Chief of Division of Water Rights in 1924, and State Engineer and Chief of the Division of Water Resources in 1927.

C. G. Gillespie has been chief engineer of the California State Department of Public Health since 1907, except for two years. He organized its Bureau of Sanitary Engineering in 1915.

E. A. Reinke in 1920 joined the forces of the Bureau of Sanitary Engineering of the California State Department of Public Health. He is now Senior Engineer.

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NUMBER 9

Going-to-the-Sun Highway Completed

Traversing an Exceedingly Rough Terrain Over Logan Pass in Glacier National Park

By JEAN EWEN

ASSISTANT HIGHWAY ENGINEER, BUREAU OF PUBLIC ROADS, PORTLAND, ORE.

SHOVEL CLEARING A SNOW SLIDE

AS a boy and young man, Mr. Ewen lived in Kalispell, Mont., when the region now known as Glacier National Park was the mecca for the town's vacationists. According to him a trip to Lake McDonald was then an adventure; a visit to the top of the immense glaciers required careful planning and extensive preparation; and a trip to upper St. Mary's Lake was nothing short of a tour of exploration. Only Indian trails existed, and even the use of pack animals was dangerous. The few adventurers who penetrated this land of mystery invariably brought back stories of unbelievably beautiful mountain scenery, the marvelous coloring of which photographs could not portray. Such beauty could not remain long unrecognized, and on May 11, 1910, Congress established Glacier National Park. Although the construction of a highway through the Park was suggested by the Director as early as 1917, it remained for Stephen T. Mather to secure the first preliminary and reconnaissance surveys for the 55-mile route over Logan Pass and to initiate construction. By 1925 a 25-mile section from McDonald Creek on the west to St. Mary's Lake on the east remained unbuilt—through the most difficult and inaccessible terrain in America. In spite of weather conditions, which permitted a working period of but 200 days a year, by 1928 the 12$^1/_2$ miles west of Logan Pass had been completed. In the meantime complete resurveys from Logan Pass to the easterly boundary of the park, 19$^1/_2$ miles, had been made. In 1931 two contracts were let for its construction and in 1933 a third. The whole route from St. Mary's to Belton was opened to automobile traffic this summer. This abstract of the paper presented by the authors before a joint session of the Highway and Construction Divisions on July 12, 1934, at the Vancouver Convention of the Society, describes the construction methods used and the steps taken to prevent unnecessary scarring of the natural cliffs and forests along this $2,250,000 high-gear road.

CONGRESS established the Glacier National Park Service on May 11, 1910, and assumed the work of administration. At that time crude wagon roads were in existence from Belton, on the west side of the Park, to the foot of Lake McDonald, a distance of three miles. On the east side a rough wagon road led to St. Mary's Lake, 35 miles from Browning. The only connection between the east and the west sides of the park was by rail via the Great Northern Railway. Automobiles had to be shipped on flat cars from Glacier Park Station to Belton.

THE BEGINNING OF A TRANSMOUNTAIN HIGHWAY

In his first annual report in 1917, the Director of the National Park Service suggested the construction of a highway through the park. Later Stephen T. Mather was appointed to the post and immediately after the War secured a preliminary and reconnaissance survey and recommended the Logan Pass route, that ultimately followed in the construction of the Going-to-the-Sun Highway (Fig. 1). The construction of the proposed 55-mile road was a stupendous undertaking under any conditions. To attempt such a project with the regular funds allotted to the National Park Service was out of the question. A program for highway development in the National Parks was launched and received the support of Congress in the form of scheduled appropriations based on a comprehensive program of road construction.

Considering Logan Pass as the middle point, the proposed road was divided into two sections designated as the west side and the east side. Under this program the engineering division of the National Park Service initiated construction with a survey from Belton on the Great Northern Railway to the head of Lake McDonald. After both sides of the lake were investigated, the route along the east shore was selected as the most practical and economical. Partly by force account and partly by contract, the 23 miles of road from Belton, along Lake McDonald and up the McDonald Creek valley to the end of the possible water grade on the west side of Logan Pass, was completed at a cost of about $180,000 by 1925.

Early in September 1924 a cooperative agreement was executed between the Bureau of Public Roads and the National Park Service, under which the Bureau was to make the location survey and prepare plans and estimates for the construction of the Going-to-the-Sun Highway across the continental divide. By the middle of September the Bureau's field party, in charge of Frank A. Kittredge, M. Am. Soc. C.E., now Chief Engineer of the National Park Service, started the survey at Logan Pass. Standards were established as follows: ruling grade, 6 per cent, with a reduction of 1 per cent in grade for each 50-ft decrease in radius below 200 ft; a minimum radius of 106 ft; and a clear roadway width of 22 ft on fills and of 16 ft, in addition to ditches 3 ft wide, in cuts.

In the selection of the route, Mr. Kittredge considered first the need for a permanent route, designed to permit future improvements without leaving objectionable scars where, for economic or other considerations, initial construction would necessitate modified standards in alignment and grades; second, the general National Park policy as to acceptable grades and alignment for safety and traffic control; third, the most favorable exposure under usual snow conditions; fourth, the maximum return in exhibiting the scenic resources of the park; and fifth, the character of the road as a transcontinental highway.

A south or west exposure was secured for practically the full length. The line was also held high on the mountain sides to avoid the shadows of the adjacent peaks. This location was considered more favorable under snow conditions, as snow storms and slides would pass over the road rather than accumulate in deep drifts or banks, an inevitable condition on a lower route. Less than a half dozen through cuts were planned.

The survey was completed on November 10, 1924. Plans and specifications were prepared in the office during the winter and bids for the construction of the West Side section, from McDonald Creek to Logan Pass, a distance of 12 miles, were opened on June 10, 1925.

CONSIDERATION OF BIDS

Several alternates were considered in the advertisement for bids. Power shovels were not thought to be the most satisfactory type of construction method for the best results as regards final appearance of the work, and hand labor by station gangs was preferred. This was estimated to cost 8 per cent more than mechanical power. However, the low bidder on the project would not submit a price on any method except that of power shovels.

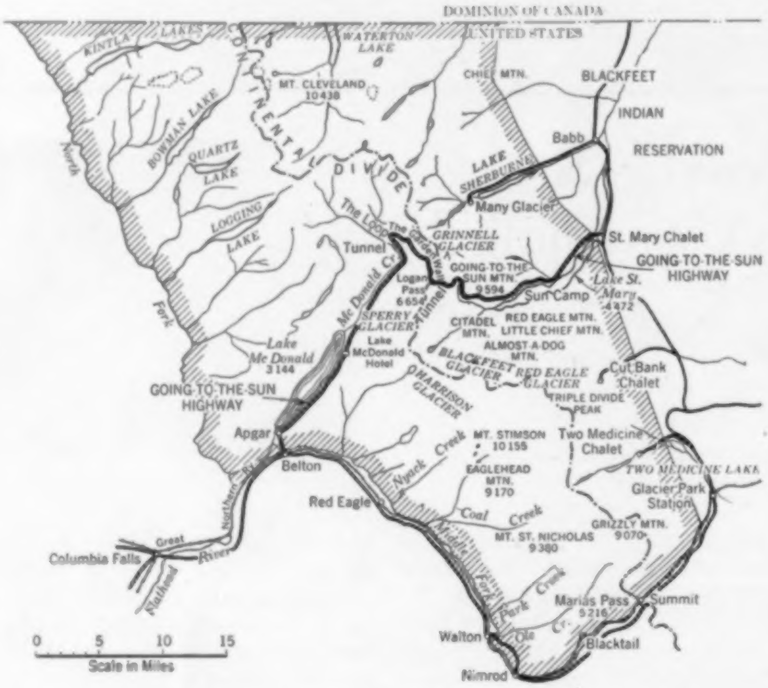


FIG. 1. GLACIER NATIONAL PARK AND THE GOING-TO-THE-SUN HIGHWAY

By the use of 12,000 cu yd of cement rubble masonry for retaining walls it was estimated that 85,000 cu yd of excavation could be eliminated. The wall type of construction was estimated by the engineers to increase the total cost of the work by 30 per cent. The low bid received, however, increased the cost of this type of construction by only 10 per cent. The contract for both grading and surfacing was awarded to Williams and Douglas of Tacoma, Wash., on their bid of \$870,000, on the basis of using power shovels and full excavation. The engineers' estimate was \$1,000,000 on comparable types of construction.

CONSTRUCTION PROBLEMS ON WEST SIDE

Conditions confronting the contractors in the construction of this high-type highway $12^1/_2$ miles in length, through the most rugged mountainous region in America, demanded the development of an efficient organization. There were no transportation facilities permitting access to the work at any point except the westerly end, which itself was 23 miles from Belton, the nearest railway point. Since the last $4^1/_2$ miles of the road from Belton was under construction, supplies and equipment could be transported over it only by pack animals. The working season was very short, not over 200 working days a year. In fact, experience showed that conditions were fully satisfactory only during the months from June to September. As the work was in a National Park, unusual care had to be exercised in the location of pioneer roads and trails to avoid unnecessary scars. The quantities involved included 90 acres of clearing; 480,000 cu yd of excavation, of which 90 per cent was estimated as rock; 16,000 cu yd of tunnel excavation; 9,200 cu yd of masonry walls, guard rails, and other structures; and 14,500 cu yd of surfacing.

This was the situation when the contractor arrived at the site toward the end of June 1925. The headquarters camp was established near Logan Creek, and Camp No. 2 above "The Loop" (Fig. 1), for the rock workers on the cliff section. Excavation was begun with a $^3/_4$-yd gas shovel, which during the first season completed the first two miles of road and built a pioneer road for the third mile to Granite Park, an impassable spur projecting into the valley. The shovel then followed the Waterton Trail for $1^1/_2$ miles to a point below The Loop before the first season closed at the end of October.

During the season of 1926 a string of 60 horses packed in materials and supplies; five more camps were established; and 15 miles of trail were built. At the peak of the season 300 men were employed. The shovel dug a road for itself up to grade and continued excavation. A second shovel was put to work west of Granite Park,

and the tunnel through the spur was begun. Compressors and metal culvert pipes were brought in over the trails on sleds pulled by horses and even men. Most of the half million pounds of explosive used on the contract was packed in. Track, cars, drill steel, hand tools, compressor pipe and hose, jackhammers, gasoline, and other construction and camp equipment went in by pack horse over the trails. Subsistence supplies kept the pack string steadily employed throughout the season. The cost of transportation by this method ran from $25 per ton at the nearest camp to $50 per ton at the farthest camp, to which only one trip per day was possible. The season ended with nearly half the project completed.

In the 1927 season a third power shovel was added. During this summer the tunnel was completed, 60 per cent of the masonry was placed, and surfacing was begun. At the time the winter shut down the project was over 80 per cent finished. The final season began late in May 1928 with three camps in operation, since work had advanced to the point where teams and trucks could be permitted on the roadbed. Excavation and masonry were completed, the surfacing was placed, and toward the end of October 1928 the West Side project was accepted.

DETAILS OF CONSTRUCTION

Clearing, which was confined to the areas within the slope stakes, was done by hand methods. On side hills a fringe of timber was left standing on the fill side as a protection to the adjacent forest area during blasting operations. This timber was later removed. All debris left from the clearing was burned, an especially hazardous operation on steep slopes at a time of the year when the forest was dry.

The mountain side from which the greater part of the west side section is carved is the base of the "Garden Wall," a part of the continental divide, and one of the most outstanding scenic features of Glacier National Park. It is difficult indeed to describe highway construction in this park in purely engineering terms. Construction, costing several millions of dollars, and employing hundreds of men for years, is considered an engineering achievement. But this highway appears merely as a faint scratch on a child's slate against this background of sheer stone, stark natural masonry—the Garden Wall. Our most ambitious projects are dwarfed by comparison with such topographic giants as the Piegan and Going-to-the-Sun mountains. Seen in perspective, only the audacity of man in attempting to bend these giants to his bidding is deserving of praise—not the work of his hands.

All roadway excavation was let on an unclassified basis, at a unit price of $1.14 per cu yd. The work was heavy everywhere. Excavation averaged more than 40,000 cu yd per mile, and grading alone cost $171,000 per mile. Numerous practically vertical cliffs were found all along the line, many of them several hundred feet high and a thousand feet long. The rock is a limestone throughout, badly fissured by frost and ice on the exterior and generally breaking in large pieces. Some cuts were as deep as 90 ft, measured on the center line of the road.

The tunnel through the rock point at Granite Park is 200 ft in length, 20 ft wide, and 18 ft high, and has a semicircular roof section. The road passes again over this same point about 400 ft higher. Two windows were driven through the sides to the full height of the tunnel to open up wonderful vistas down the McDonald Creek valley.

For culverts, corrugated galvanized metal pipe from 18 to 36 in. in diameter, with cement rubble masonry head walls, was used throughout, according to the standard practice of the Bureau. The head walls for the larger size of pipe were constructed to give the appearance of arch culverts. Three small arched cement rubble masonry culverts and two concrete box culverts were constructed. The head walls for the latter were also of rubble masonry and also designed as arched outlets.

Surfacing was specified as two-course crushed rock or gravel, the base course material passing a $1^1/_2$-in. screen and the top course, a $^3/_4$-in. screen. Each course is 4 in. deep and 16 ft wide. The character of the material, limestone, required but very little binder. The base course was omitted in the upper four miles of the project since the subbase was entirely of rock.

GEOLOGIC HISTORY OF THE PARK

Before a description of construction operations on the east side of Logan Pass is given, a brief consideration of the geologic history of Glacier National Park is necessary. One of the characteristics of the formation is the many folds in the rocks and the breaks or faults cutting across the layers. The oldest rocks in the region are found to be resting on the youngest rocks of the adjacent plains. In explanation of the phenomenon, geologists offer the theory of the Lewis overthrust.

According to this theory, forces deep in the earth slowly gathered energy until finally the stress became so great that the rocky crust began to move from the west slowly toward the plains. The rocks of the plains were evidently immovable, and the stresses accumulated until they found relief by folding the rocks. The pressure, although slightly relieved by the bending, persisted, and the folds were further enlarged until ultimately the strata broke. As a result of this fracture the rocks on the west side of the folds were pushed upward and over the rocks on the east. It has been estimated that the rocks in the Lewis overthrust have moved a distance of at least 15 miles.

During this period of formation, streams began to wear the rocky mass and to cut deep canyons in the upland part. The rocks of the mountains, owing to their resistant character, were not worn away as rapidly as those of the plains. Where the older, more massive strata overlie the soft rocks, the mountains are terminated by precipitous walls, which explains the absence of foothills along this mountain front, a feature in which it differs from most ranges. It is also evident that the construction of a road from the summit to the plains on the east side of the mountains must penetrate all the various strata exposed in this overthrust formation. The rock is variable in hardness as well as in structure. It appears almost uniformly at an angle of 30 deg from the horizontal and badly laminated. It breaks badly in blocks of from 2 to 3 cu yd, and is very difficult to drill. In the same ledge some of the rock broke in blocks and some along curved surfaces. The formation is limestone and varies from dark gray to brilliant reds, greens, and yellows.

CONSTRUCTION ORGANIZATION FOR EAST SIDE PROJECT

Grading of the east side section, a distance of $19^1/_2$ miles from Logan Pass to St. Mary, was let in three contracts. Early in June 1931, two of these were awarded: one for 5.7 miles from Logan Pass east, to the Colonial Building Company of Spokane, on its bid of $385,000, and the other for the next 4.5 miles to A. Guthrie and Company at $200,000. Both contractors

BRINGING IN CAMP LUMBER BY PACK TRAIN

RUN-OFF FROM MELTING SNOW

UNDERCUT FOR A HALF TUNNEL SECTION

started in the middle of June, and each was allowed 300 calendar days for completion. The third grading contract, for the final 8 miles to St. Mary, was let in 1933 to A. R. Douglas at a price of $80,000.

The Colonial Building Company organized its construction forces into two camps, one of 120 men to operate from Logan Pass east; the other of 75 men to start from the east end of the project and work west. A tunnel was required through a point about one mile east of Logan Pass, since it was impossible to pioneer around this point. The slopes beyond for a distance of another half mile were almost vertical, too steep even for hand work.

For access to this part of the work the crew working from the western terminus at Logan Pass had the previously constructed road from Belton. The east end, however, was still without a connection, being over a mile distant from the west end of Lake St. Mary. The contractor had two pontoons, of 60-ton capacity, constructed in Seattle, and a 30-ft gasoline launch in Kalispell, Mont. This equipment was shipped by rail to Glacier Park, and thence by truck 32 miles to the lower end of Lake St. Mary, where it was launched and assembled.

CONSTRUCTION OF NEW TRAILS

Two gas shovels, one of $1^1/_2$-cu yd and one of $^3/_4$-cu yd capacity, were walked for 38 miles from the railroad to a dock on the lake and then brought by the pontoons and the launch to the upper end of the lake, a distance of $4^1/_2$ miles. The difference in elevation at this point between the lake and the right-of-way is 250 ft. The $^3/_4$-yd shovel was used to build a "tote road" and then advanced within the highway clearing a further distance of $2^1/_2$ miles to the camp for the lower section.

A new trail had to be constructed above the road location from Logan Pass for a distance of $3^1/_2$ miles to Piegan Creek, for the accommodation of tourist traffic as well as to give access to the tunnel site for construction ahead of the shovel, which started at Logan Pass. At this point a switchback trail, descending 100 ft in a distance of 300 ft, led from the platform built for the compressor to the edge of a cliff, whence a vertical ladder extended 100 ft lower to the bench at the east tunnel portal. All supplies for this advance work were hauled over the trail by a caterpillar tractor and sleds from Logan Pass, over a mile distant, and packed down the trail and the ladder.

At times the contractors gambled with their equipment at long odds, but they won. Once a $1^1/_4$-yd shovel was lowered on its main-line cable more than 25 ft over a nearly vertical cliff to a talus slide. A caterpillar tractor used on the upper section went over the cliff while attempting to drag a huge boulder, but it was not damaged and walked back to the grade under its own power. Lake transportation was rather hazardous during storms, and frequently the service was tied up for several days on account of severe winds. Relatively little hand work was done on this contract, the power shovels being used almost exclusively.

About 16,000 cu yd of "Type B" excavation was performed by hand work over an 800-ft section west of the tunnel. "Type B" excavation was that specified where damage to roadbed, slopes, and surrounding objects could not be prevented except by using extraordinary precautions. For it, blasting operations had to be so conducted that absolutely no damage would result. This might necessitate drill holes to be spaced not over 2 ft apart; the use of not over $^1/_2$ lb of explosive per cubic yard; the shooting of only a few holes simultaneously; and even mats to smother the blasts. No overbreak was allowed on designated "Type B" excavation units, and payment for this work was made under a separate item in the bid schedule.

On October 8, 1932, the first car came over the new grade from Lake St. Mary to Logan Pass, and on October 17 the project was completed. The final estimate totaled over 356,000 cu yd of excavation and 315,000 station yards of overhaul, an excellent record under the conditions encountered in Glacier National Park.

Logan Pass is at an elevation of 6,654 ft. The grade on the east side averages $5^1/_2$ per cent, and the maximum is 6 per cent for $6^1/_2$ miles from the pass. Along Lake St. Mary the grade is undulating. The section used is slightly wider on the east side than on the west. A 24-ft roadbed was constructed with a minimum width of 3 ft for ditches in rock sections. Ditches in common material were made 6 ft wide, with a 4 to 1 slope from the roadbed shoulder to the bottom of the ditch. Cut slopes in earthy material were constructed on 2 to 1 slopes, and the top and ends of the cuts were rounded to merge into the original topography.

A mile east of Logan Pass is the tunnel, which is 408 ft in length, 26 ft wide, and nearly 20 ft high. The roof is designed on a 14-ft radius in the center and on 8-ft radius at the haunches, with the springing line 9 ft above grade. Concrete curbs 14 in. high and 6 in. thick, and a gutter 2 ft wide over-all, were constructed on each side. For a distance of 25 ft from each portal the concrete work was colored to approximate the tone of the native rock. Thence it was gradually lightened to its natural shade more definitely to define the margin of the travel way for the drivers. No lining was required.

Sand for the masonry on the upper section was hauled 70 miles from Kalispell and cost $6 per cu yd at the site. Gravel and sand for the box culvert were produced with the aid of the $^3/_4$-yd shovel on the south shore of Lake St. Mary, and the pontoons were used to transport the equipment and the material.

DIFFICULTIES IN EXCAVATION

An existing road to Sun Camp Chalet, approximately $1^1/_2$ miles west of the east end of the project, made accessible the $4^1/_2$-mile section awarded to A. Guthrie and Company. The principal features of this project were the high cliffs near the east end, around which a trestle had to be constructed to enable the shovel to pass; the grading of a $^1/_4$-mile spur road with a Y-connection to the Sun Camp Chalets and parking

A Tunnel Portal

Starting a Tunnel

Masonry Construction at the Loop

areas, involving 30,000 cu yd of "Type B" excavation; and construction of the Baring Creek Bridge, an earth-filled spandrel arch of reinforced concrete, 72 ft long, having cement rubble masonry facing and spandrel walls and railing.

Only one shovel was used on the project, a $1^1/_4$-yd gas-electric machine. A caterpillar with a hydraulic scraper and bulldozer were also used to a limited extent. Traffic interfered with the construction of this section more than with that of the Colonial Building Company's contract adjoining it on the west. Throughout the season auto stages operated on a regular schedule to Sun Camp, one of the most popular resorts in the Park.

Of the total of 160,000 cu yd of excavation, 25 per cent was across the face of high cliffs of solid rock, requiring considerable hand labor for trimming the slopes and prying off loose rock—slow, dangerous, and expensive work. The construction of a spur road and parking areas in the vicinity of Sun Camp was specified mainly for the protection of the buildings and tourist guests of the camp. In this, 30,000 cu yd of "Type B" excavation was involved. Unit prices were 73 cents per cu yd for unclassified excavation and 88 cents for "Type B" excavation.

The grading of the last section of the Going-to-the-Sun Highway was awarded to A. R. Douglas and was started early in June 1933 but was not quite completed last year. The contractor has resumed work again this year and is expected to finish during the summer of 1934. This is the lightest section on the entire route. It follows the north shore of Lake St. Mary for its full length, through light scattered forests and frequent mountain meadows with an abundance of alpine flowers and a riot of color throughout the season. The average elevation on this part of the route is 4,500 ft. This is the exit section from the Park; the road emerges into the great plains at St. Mary.

Completing the East Side Project

A contract for surfacing the entire east side project, 19.5 miles from Logan Pass to St. Mary, was awarded this spring to the Lawler Corporation of Butte, Mont., for \$260,000. The estimate includes 50,000 tons of crushed stone for the bottom course, 30,000 tons for the top course, 8,000 tons for maintenance, and 27,000 tons for subbase. The subbase course is planned to be from 2 to 12 in. in depth, depending on the character of the subgrade. The bottom course will be 4 in. thick and the top course 2 in. thick, all for the full width of the roadbed.

The work is to be completed in 210 calendar days, allowance being made for periods of shutdown during the winter. It therefore may be expected that it will be finished next year.

Bids were also opened recently for bridges over St. Mary's River and Divide Creek. The St. Mary's River Bridge will be a massive and imposing structure, with three flat segmental arches of reinforced concrete over a total length of 140 ft, faced with cement rubble masonry. Piers and abutments will also be of rubble masonry with concrete slab footings. The Divide Creek Bridge will be a deck-slab structure with two 16-ft spans and one 20-ft span, concrete piers and abutments, and rubble masonry railing. The completion of this work is expected during the 1935 season.

Several of the contractors who had completed sections of the Going-to-the-Sun Highway were asked for their stories of construction problems. None, however, considered the work as unusual in any way, and none believed the methods followed or organization established on his own particular section to be any departure from usual practice. It was just another job. However, each seemed to entertain the highest respect and admiration for the others, the unanimous opinion being that the "other" contractors all had very difficult jobs.

None of the contractors, it is believed, lost money on his contract. It may be an open question whether their profits could have been increased. The reason for the wide variation in methods used is perhaps obscure. The success of the method chosen in a particular case was probably due more to the care and ingenuity of the individual contractor in its application than to the intrinsic merits of the method itself.

A compilation of the principal items of work, summarized as follows for the entire 55 miles of the Going-to-the-Sun Highway, from Belton, the western entrance to Glacier National Park, to St. Mary, on the eastern boundary, may serve as a comprehensive index to the size of the project:

Clearing	275 acres
Excavation, all types	1,500,000 cu yd
Cement rubble masonry	16,000 cu yd
Surfacing	100,000 cu yd
Concrete	2,500 cu yd
Culvert pipe	20,000 lin ft

The total cost, including all expenditures prior to the time the Bureau of Public Roads took over the supervision of the highway and the cost of all surveys and construction engineering, is \$2,500,000.

The greatest achievement in the construction of the Going-to-the-Sun Highway is not its character as an engineering feat. This must be considered only secondary to its greater function, that of making accessible to modern transportation the age-old wonders of the engineering of time and the elements—the movement and construction of a range of mountains, the excavation of great channels by glaciers whose probable dimensions must tax even the most vivid imagination. Our only prayer must be that our work may be truly a component part of this wonder of nature, that we may not have marred that which we, with all our science, knowledge, and experience, could never reproduce.

From 1925 to 1928, W. G. Peters, Associate Highway Engineer of the Bureau of Public Roads, was resident engineer for the Bureau during the construction of the West Side Project, and since 1930 A. V. Emery, Assistant Highway Engineer, has been resident engineer on the East Side Project. These men contributed the data from which this article has been prepared.

hand work was done on this contract, the power shovels being used almost exclusively.

pass; the grading of a 1/4-mile spur road with a Y-connection to the Sun Camp Chalets and parking

Keeping a Domestic Water Supply Safe

Sanitary Engineering Experiences with a Large Public Enterprise in the West

By J. D. DeCosta

Associate Member American Society of Civil Engineers

Engineer in Charge of Distribution, East Bay Municipal Utility District, Oakland, Calif.

In the average large water supply system of today the duties of a sanitary engineer are not confined to the filtration of water, but include watershed sanitation, rural sewage disposal, camp sanitation, biological control of reservoirs, sterilization of new pipe lines, design and construction of new water treatment works, mosquito control, and even soil technology. The protection of a municipal water supply requires eternal vigilance from the time the water arrives on the watershed until it is delivered at the consumer's tap. The following article is an abstract of the paper presented before the Sanitary Engineering Division of the Society on July 12, 1934, at the Vancouver Convention, by Mr. DeCosta, who speaks from long experience in this work.

In the past, many communities have secured water supplies at great expense, with entire disregard for quality. The main object was to obtain an adequate quantity. In more recent years, however, increased progress in the art of water treatment, together with public demand for better water, has caused governmental agencies to raise the standard of quality to the point where it has become increasingly difficult for a water purveyor to serve other than a reasonably safe and palatable water.

Governmental agencies have been concerned mostly with the bacterial safety of the water, which is perhaps as it should be, and have left its physical appearance and general potability to the water works official. This official, however, as a rule is content to meet the bacterial standards of the Treasury Department, and even boasts if there are fewer bacteria in the water than the Treasury Department allows, when most of the time the water is unsatisfactory for drinking purposes. The fact that consumers have to buy bottled water and install household filters or water softeners appears to be a secondary consideration. One measure of quality is the number of complaints registered by consumers, and unfortunately too many water works officials are prone to accept this standard rather than to improve the quality of the supply as their knowledge and better judgment dictate.

FILTERED SURFACE WATER FOR EAST BAY DISTRICT

About a half million people on the east shore of San Francisco Bay are served by the East Bay Municipal Utility District. The average daily consumption is about 35 mgd, or 70 gal per person per day. The daily consumption varies from 25 mgd during the rainy season to 50 mgd on hot summer days, and it is estimated that the hourly maximum reaches the rate of 200 mgd. The supply consists entirely of filtered surface water. A small part is obtained from 75 sq miles of drainage area tributary to the local impounding and terminal reservoirs. The principal source of supply is the Mokelumne River, from which water is impounded in the Pardee Reservoir, approximately 90 miles distant from the Bay cities. In the entire system there are five storage reservoirs with a capacity of almost 100 billion gallons. In 1918 the net safe yield of the local drainage area was estimated to be about 30 mgd. A series of abnormally dry years has reduced this amount to about 20 mgd. Last year the run-off just balanced evaporation and seepage losses, and this year these losses, which average about 45 in. per year, are greater than the run-off.

The District operates four rapid sand plants, through which all the water is filtered before delivery to the consumer. The water in the local reservoirs varies in hardness from 45 to 115 ppm. Mokelumne River water has a total hardness of 24 ppm. Since the various waters are mixed in the distributing reservoirs, the hardness of the water reaching consumers seldom exceeds 60 ppm, which it is believed is ideal for both domestic and industrial purposes.

During the past ten years a program of sanitation has been developed which, although not extremely technical, is believed to be practical for operating a surface water supply system. To guard against infectious bacteria, the entire supply is protected by four distinct and well-defined barriers or lines of defense, as follows: (1) protection at the source of supply, (2) long period of storage, (3) filtration, and (4) sterilization. The various steps taken in the purification process are shown schematically in the diagram in Fig. 1.

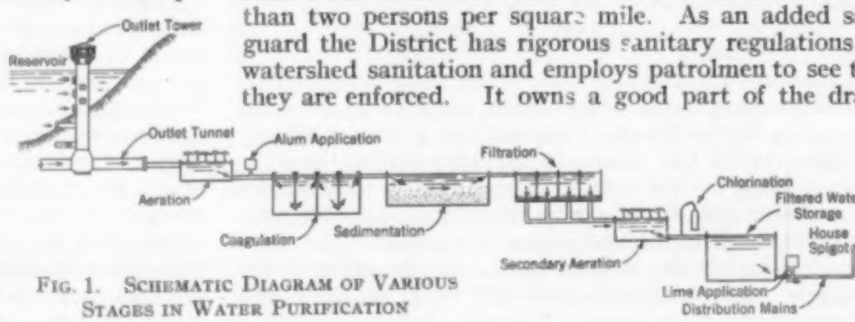


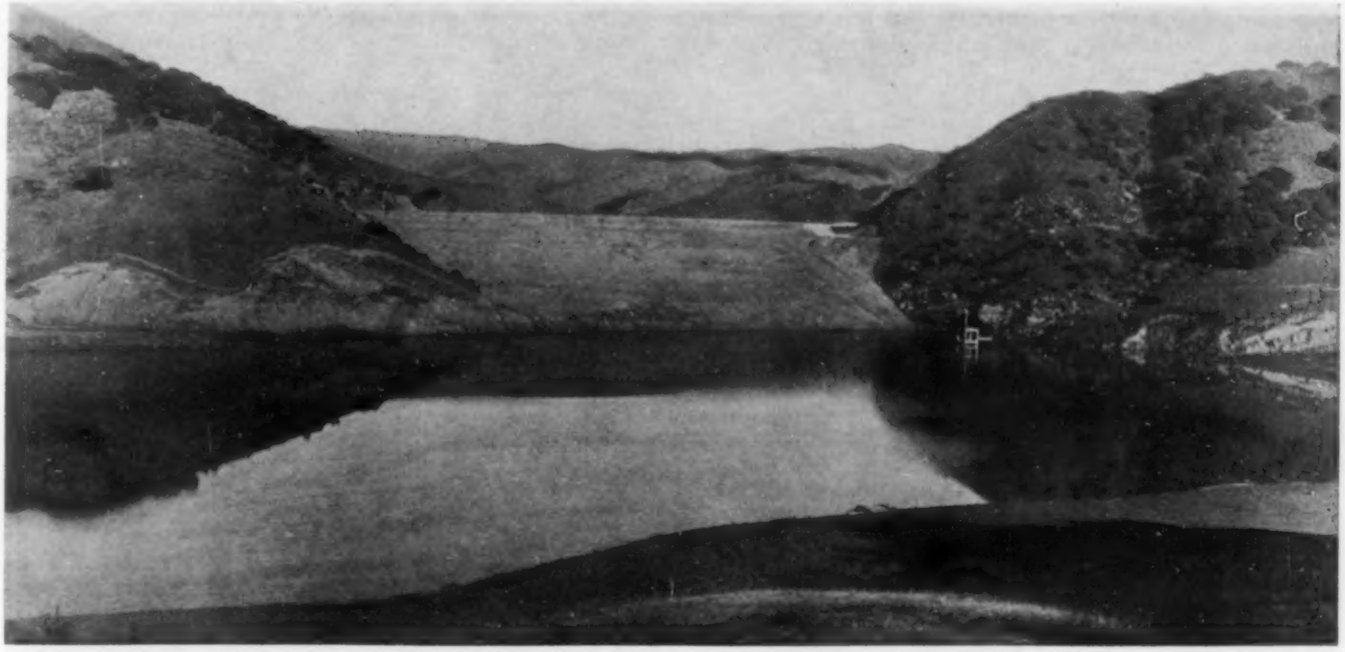
Fig. 1. Schematic Diagram of Various Stages in Water Purification

The first line of defense involves watershed sanitation. At the source of supply the objective is to prevent dangerous contamination. Inasmuch as the greatest danger is connected with human existence, an uninhabited or sparsely settled catchment area will produce the safest water. The average population on the watershed from which the District obtains its water is less than two persons per square mile. As an added safeguard the District has rigorous sanitary regulations for watershed sanitation and employs patrolmen to see that they are enforced. It owns a good part of the drainage area and exercises sanitary supervision over all of it.

A second line of defense is provided by a long period of storage in the unusually large impounding and terminal storage reservoirs. Water is an unfavorable environment for pathogenic bacteria, whose normal habitat is the human organism. There they find living conditions ideal for growth and rapid multiplication.

over a total length of 140 ft, faced with cement rubble masonry. Piers and abutments will also be of rubble

East Side Project. These men contributed the data from which this article has been prepared.



UPPER SAN LEANDRO DAM AND RESERVOIR

When they are deposited in water, which usually occurs through the medium of sewage, they immediately start to die out. The factors that affect their death rate are sunlight, temperature, natural sedimentation, predatory organisms, and time. The combination of good watershed sanitation and large size of storage reservoirs has produced a water which the District's laboratory records show is safe for human consumption most of the time. Moreover, it is believed that the few colon bacilli that are found are of animal origin and have no hygienic significance. This fact, however, does not lessen the District's care and vigilance in controlling the operation of the filter plants and chlorinating stations. In fact, every man in the Sanitary Department is trained to exercise the same diligence that is required in treating water from a heavily polluted source.

CONTROL OF TASTES AND ODORS

In the first two lines of defense the bacterial safety of the water is practically taken care of, so that the function of the filter plants is primarily to improve the physical characteristics of the supply. Some of these, such as taste and odor, are also controlled at the source, which leaves a minimum amount of work for the plants to do.

In the District's supply, as in most surface water supplies, the three possible causes of foreign tastes and odors are chlorine, chlorine by-products, and algae. Chlorine taste is due to faulty application of the chemical and seldom if ever occurs in a properly operated plant. Algal tastes and odors are more common, and their prevention is one of the most difficult problems confronting the water works engineer. This is particularly true in California, where climatic conditions are most favorable for luxuriant growths. Tastes and odors due to by-products of chlorine usually accompany plankton growths, so that as a rule proper control of the plankton will prevent this trouble.

Experience in handling local waters has shown that certain microscopic organisms are particularly troublesome. Ordinary treatment will not remove the taste or odor caused by them; consequently, when any of these particular organisms are found in a reservoir, the water is immediately treated with copper sulfate. This method of prevention at the source has proved to be both more effective and more economical than efforts to eliminate the taste or odor in the treatment plants.

As regards biological control, the methods employed by the District are somewhat different from general practice. The plankton net is used in place of the Sedgwick rafter method. Also, the measurement of the catch, instead of being expressed in number of organisms per cubic centimeter or other standard unit, is made volumetrically, and the organisms are listed in the order of their prominence. The field work is done by the caretaker at each reservoir. These men are tra ned to collect the net samples, make dissolved oxygen tests, and record the temperature of both top and bottom water. Field tests are made and net samples gathered at least twice each week. The volume of the organisms is determined by transferring them to a graduated tube, killing them with formaldehyde, and allowing them to settle or float to the surface as the case may be. After a period of 24 hr the field man records the volume of the organisms, transfers the catch to a 4-oz bottle, and takes the sample to the laboratory for microscopic examination.

In addition to this routine sampling, a net catch is collected daily during the algae season and immediately taken to the laboratory for qualitative analysis. In this way a close check is made of the plankton life in the various reservoirs, and the growth of the more objectionable species is prevented. From the field records the plankton catch is computed in parts per million and the dissolved oxygen, as a percentage of complete saturation. These values, together with the temperature, are plotted for a permanent biological record.

It has been found that the most troublesome organisms are anabaena, aphanizomenon, volvox, and ceratium. No doubt there are other species that will cause trouble if their concentration is great enough, but so far those mentioned are the only ones for which storage reservoirs have been treated. Some of the reservoirs have been treated to destroy growths of diatoms, not because of trouble with taste or odor but because of their effect in shortening filter runs.

PARDEE DAM ON MOKELUMNE RIVER; MAIN STORAGE OF SUPPLY FOR EAST BAY CITIES

This apparently unscientific method of biological control has almost eliminated algal tastes and odors. Copper sulfate treatment is not costly, especially in the small quantities used by the District. The dosages recommended in textbooks are followed very closely, but the total quantity used is based on the top 10 ft of water instead of the total volume in the reservoir and in some instances amounts to as little as 10 per cent of the quantity of copper sulfate that would otherwise be required. This dosage was arrived at by a process of elimination. First, the dosage was based on the total volume in the reservoir, according to common practice. This was progressively reduced until finally the quantity required for a particular organism was based on the top 5 ft of water. When this base proved inadequate in a number of instances, the volume of the top 10 ft of water was finally adopted for determining the quantity of copper sulfate required. This method has been effective in destroying the algal growths, and there has been a considerable saving in copper sulfate. Its effectiveness in preventing tastes and odors due to algae, as well as to chlorine by-products, is made evident by the fact that in the past five years there has been no complaint of taste or odor that could be traced to the source of supply.

FILTRATION PLANTS

Since problems of taste, odor, and bacterial content are solved at the source of supply, there is little for the filter plants to do other than improve the physical appearance of the water. The District operates three rapid sand plants with a combined nominal capacity of 43 mgd and has as a stand-by one pressure filter plant of 6-mgd capacity. The excellent quality of the raw water permits the operation of these plants at an overload of 50 per cent without any loss in the quality of the effluent. The treatment process comprises primary and secondary aeration, coagulation, sedimentation, filtration, chlorination, and lime treatment to adjust the pH value. The plants are of conventional design and are operated in the usual manner.

Perhaps the greatest deviation from standard practice is that the pretreatment works are operated so that the filters have to do most of the work. This results in a much lower dose of coagulant, which after all is about the only saving in expenditure that can be made in the operation of a plant, assuming that fixed charges are at the lowest level.

Experiments have been conducted with the various coagulants and combinations of coagulants available, but thus far the results show that with the water being treated, alum is the most economical and satisfactory. It has been applied to the water before and after aeration with both good and bad results. The purpose of applying it before aeration has been to secure removal of some of the carbon dioxide produced by the alum treatment. Experience shows that the effectiveness of the method depends, among other things, on the pH value of the raw water, the amount of alum dose, and the optimum pH value for coagulation. If, owing to one or more of these conditions, the pH value of the aerated water is increased above the optimum for the best coagulation, a poor floc is obtained and more alum is required to produce the desired results. The increase in the amount of alum required often more than offsets the savings effected in lime. As a result it is found that most of the time it is more economical to apply the alum after aeration.

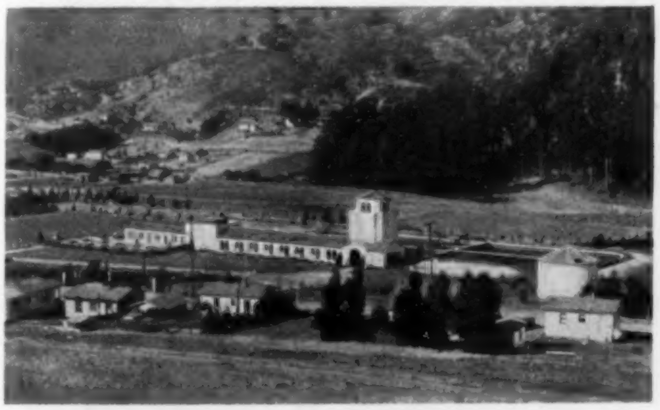
ELIMINATION OF TROUBLES WITH RED WATER

In June of 1929, when the soft Mokelumne River water, with its total hardness of 24 ppm, became available, the local reservoirs were very low and the water

that reached the filter plants was largely of Mokelumne origin. In flowing through the local reservoirs this new supply gathered a great deal of turbidity, requiring a high alum dose for proper clarification. The result was an extremely "aggressive" water—average pH value 5.8—which soon dissolved the lime incrustation in the mains and gave rise to complaints of rusty or red water throughout the entire system. Provision was made immediately to adjust the pH value of the water by adding hydrated lime to the filter effluent to raise its pH value to 8.8. But the damage had been done and even with the high pH value, it took over three months to eliminate the troubles with red water. A high pH value—8.4 to 8.6—has been maintained in order to deposit a film of calcium carbonate on the walls of the pipe as further protection against corrosion. The saturation point for calcium carbonate in the present supply is at a pH value of 8.2. Notwithstanding the high dosage of lime, no trouble has been experienced with suspended lime in the water that reaches the consumer. No doubt there are traces of suspended lime in the water at times, but apparently not enough to be objectionable. Although the water enters the system with an average pH value of 8.5, at the far ends of the mains this drops to 8.2 and often lower. Lime treatment for the water of the East Bay Municipal Utility District has proved indispensable. Moreover, it is believed that this treatment will save the taxpayers of the District a considerable amount by increasing the life of the distribution mains.

OTHER ECONOMIES EFFECTED

In connection with the lime treatment, laboratory studies showed that considerable carbon dioxide could be removed by aeration. Consequently, at a sacrifice of both head and storage capacity, a cascade flume aerator was built in the 6-million gallon reservoir for filtered water at the San Pablo plant. With this nominal



Upper San Leandro Filter Plant
Aerator and Settling Basins at Right

amount of aeration, the savings in lime are from 30 to 60 per cent, depending on the pH value of the raw water and the alum dosage. The savings effected in the first year paid for the construction of the aerator.

A further saving in the cost of lime treatment was secured in 1933 by installing a continuous lime slaker to permit the use of quicklime, which is lower in cost and higher in calcium content. The slaker is a home-made affair which operates in conjunction with a dry-feed machine. The lime dosage is regulated through the latter and dropped into the slaker, where it is hydrated. The hydrated lime then flows through a settling cone, in which grit and other insoluble matter are settled out. From the settling cone the milk of lime is conveyed to the point of application.

Another feature of plant operation that may vary somewhat from general practice is the frequency with which the sedimentation basins are cleaned. They

Claremont Laboratory at West Portal of Claremont Tunnel
Also Contains Pumping Plant and Substation

are never allowed to go longer than two months without being cleaned, even though they contain an accumulation of sludge of only a few inches, because here again experience has shown that taste- and odor-producing substances are frequently imparted to the water by the putrefaction of the sludge. This is particularly true during the summer months, when the sludge is composed largely of organic substances.

Activated carbon is kept on hand for emergencies, but to date there has been only one occasion for its use. This occurred at the Grant Miller Plant, which supplies the towns of Lafayette and Saranap with about 50,000 gal per day. Normally this plant is supplied with Mokelumne water, which requires very little treatment; but for two months during the summer of 1932 the Mokelumne aqueduct was taken out of service for repairs, and it became necessary to use water from the Lafayette Reservoir. Early in the spring 200 million gallons of water had been pumped into this reservoir, submerging several acres of former pasture land, on which there was a large accumulation of organic matter.

By midsummer the reservoir water had become entirely depleted of oxygen and was thoroughly impregnated with the by-products of anaerobic decomposition. Powdered activated carbon was mixed with alum in the proper proportions for an alum dose of 3 grams per gal and a carbon dose of 0.5 grams per gal, which laboratory studies showed were about the correct amounts. The mixture was applied to the water by means of the ordinary dry-feed machine. Besides the addition of carbon, the water received the usual treatment. Results exceeded the most optimistic expectations; the filter effluent was crystal clear and free from taste and odor. In fact, the consumers were never aware that a change had been made in their supply.

Chlorine treatment constitutes the fourth and last line of defense against pathogenic bacteria. Enough of this chemical is applied to the filtered water at each plant to give a residual of one-half to three-quarters of a pound of chlorine per million gallons of water, despite the fact that even the raw water is bacterially safe for human consumption most of the time and that the filter effluent seldom shows any sign of B. coli contamination.

The delivery of first-class water to the distribution system should complete the work of the Sanitary Department, but it does not. There are dead ends and dirty mains to flush, cross connections to be eliminated, consumers' complaints to answer, and numerous other details to take care of—all of which come under the supervision of the Sanitary Engineer. The territory supplied by the East Bay Municipal Utility District consists of broken topography that varies in elevation from sea level to 1,500 ft. There are 62 pressure zones, with the usual dividing gates. Each closed gate valve on a zone line creates two dead ends, and in addition to these there are 2,200 dead ends provided with blow-offs.

OPERATING FLOOR OF SAN PABLO FILTRATION PLANT

All the dead ends are flushed on an average of twice each year, and some are flushed every two or three weeks.

Built in the days before filtration and biological control, a large part of the present distribution system has carried unfiltered water. This resulted in the accumulation in the larger mains of large quantities of organic and inorganic matter, which never has, and probably never will be entirely flushed out. In 1931 the entire system was given a thorough and systematic flushing. A program was prepared, and written instructions were given to the foreman of each flushing crew.

Briefly, the method consisted of isolating a few thousand feet of pipe at a time by closing valves, then opening fire hydrants and blow-off valves until the pressure in the main dropped to 15 lb. This arrangement gave the maximum scouring velocity obtainable and still none of the consumers was entirely without water. The size of district flushed at one time depended on the size of the mains, the pressures in them, and the capacities of the gutters to carry off the water. In some parts of the District practically no flushing was possible. Large quantities of sludge were removed from most of the mains, but some are still dirty, as is evidenced by complaints of turbid water received from certain sections whenever there is some local disturbance, such as a shutdown for repairs or a large fire. Most of the flushing was done during the night so as to cause the consumers the least amount of inconvenience.

CROSS CONNECTIONS WITH PRIVATE SUPPLIES ELIMINATED

In the early development of the East Bay area, building was largely confined to the lower lands where comparatively good water could be obtained from shallow wells. As the community grew and water supply systems were constructed, connections were installed for many consumers to supplement their well supply. The same held true for industries, with the result that there were thousands of cross connections between the public water supply and private wells. In some instances industries along the waterfront pumped salt water direct from the bay for fire protection and other purposes.

Although the potential danger of cross connections to the health of the community had been appreciated for many years, no concerted action was taken to eliminate them until 1931. At that time the District started a survey of the cross connections in the system. On its completion in 1932, a conference was held with representatives of the U. S. Public Health Service, the State Department of Public Health, and the local county and city health officers. The existing conditions regarding cross connections were thoroughly considered and discussed, and various plans for their elimination were outlined. As a result, the State Director of Public Health issued an order to the District as of March 21, 1932, requesting that all cross connections be eliminated by January 1, 1933.

The District immediately began a program to secure compliance with this order. Every secondary source of supply was inspected for a cross connection. Detailed data were obtained on the secondary supply; a sketch was made of the piping showing the connection between the two systems; and a bacterial and chemical analysis was made of the water. Of over 2,000 secondary supplies investigated, 408 were found to be cross-connected with the public water system. By December 1932 all the cross connections had been eliminated in the following ways:

Service discontinued	51
Public supply carried over top of tank	68
Two supplies disconnected	183
Private supply abandoned	18
Double check valves installed	88
Total	408

The successful completion of this program closed the last avenue against serious contamination of the public water supply. Where double check valves are in use, they are inspected by District representatives twice each year. Furthermore, the District is always on the lookout for new cross connections or the reconnection of old ones.

Despite the condition of some of the older mains, the quality of the water reaching the consumer is uniformly good. The people in the East Bay area have been served with filtered water for many years and as a consequence have become very critical of the quality of their water. The total number of complaints relating to quality average less than one per day, and many of them are unconfirmed by investigation. In every case the cause of the trouble has been local, such as a dead end or a local disturbance in the immediate vicinity caused by a fire or a break in a pipe line requiring a shutdown for repairs.

The cost of water purification is always of interest, both to the water works engineer and to the consumer. The average cost of filter plant operation for the past four years has been $5.65 per million gallons of water filtered and delivered to the system. This includes overhead and all operating costs and amounts to 15 cents per person per year. Interest and depreciation on the capital investment at the rate of 7 per cent amounts to 14 cents per person per year, or a total of 29 cents per capita. At this rate the cost of filtered water to the average family of four is $1.16 per year, which is a very small amount to pay for first-class water.

Developing the Columbia River Drainage Basin

Problems of Improvement in Canada and the United States Discussed

OWING to the potentialities of the Columbia River system for cheap power, for irrigation, and in its lower reaches, for navigation by ocean-going ships, this stream has received considerable attention during the present economic emergency. Two huge dams for power development are under contract, the Bonneville Dam, at the approximate head of tidewater, and the Low Dam at the head of the Grand Coulee. The first article in this symposium outlines the early history of the region and describes the Canadian part of the watershed. The other three articles deal with the purposes, plans, and construction methods contemplated for the dams at Bonneville and the Grand Coulee. All four articles are abstracts of papers read at the Annual Convention of the Society in Vancouver, B.C., on July 11, 1934.

Aspects of the Problem in Canada

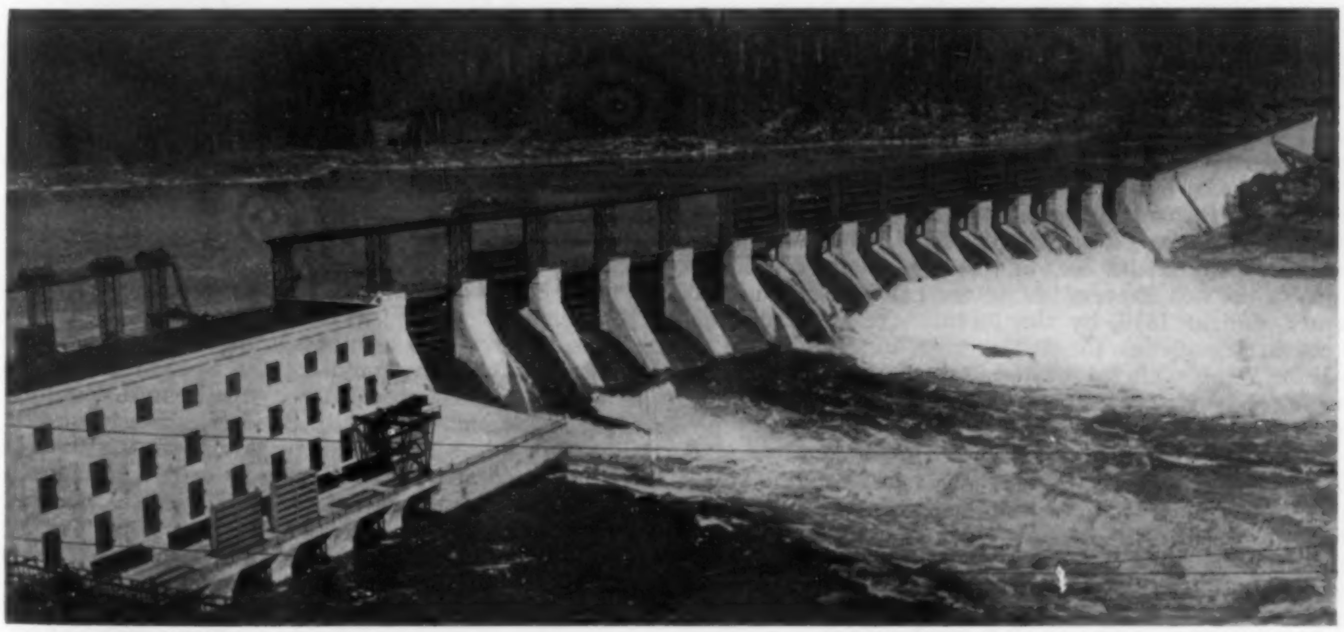
By J. C. MacDonald

Controller of Water Rights, Province of British Columbia
Victoria, B.C., Canada

THOSE parts of the Columbia River and its tributaries which lie north of the international boundary are relatively of much less importance than those to the south. With the exception of the Skagit River and one or two negligible streams near the coast, the Columbia and its tributaries are the only streams which cross the international boundary west of the continental divide. The Flathead, the Kootenay, and the Pend d'Oreille (or Clark's Fork), the Kettle, the Okanagan, the Similkameen, are all parts of the great Columbia system shown in Fig. 1.

The uses and development of the river constitute the main international water problem on the west coast. Fortunately, there are few phases of the question that are likely to be in any way contentious, but if the early history of the Pacific Coast had been different, the situation might have been quite otherwise.

Perhaps the most magnificent gift in recorded history is that of Pope Alexander VI to the Court of Spain, when he gave to His Catholic Majesty the Pacific Ocean and lands bordering thereon. This was in 1493. The title so acquired by Spain was strengthened by a vigorous policy of exploration, settlement, and spoliation. Although Queen Elizabeth of England expressed her disregard of the exclusive Spanish right, the first serious challenge came from the Russians, who, attracted by the fur trade, came down from the north and set up several establishments in the Aleutian Islands. The Spaniards investigated these Russian activities and remonstrated to the Russian Government but apparently decided to



Downstream Side of Corra Linn Hydro-Electric Plant
West Kootenay Power and Light Company Development on Kootenay River, British Columbia, Canada

limit their claims to the coast south of latitude 54°40′.

In 1776 Captain Cook set out from England by way of the Cape of Good Hope to locate the western end of the long-sought Northwest Passage. At Plymouth he anchored beside three ships of the Royal Navy, which were awaiting favorable weather to sail with the last division of Hessian troops that took part in the War of the American Revolution. Cook was strictly enjoined not to interfere with Spanish ships or settlements on the Pacific Coast. His ships returned to England with stories of the great wealth of furs on the coast and of the possibilities of trade in these commodities with China. Within a few years adventurers from England and the eastern coast of the newly formed United States of America were actively engaged in the new trade and were having their troubles with the Spaniards. The difficulties became so serious that England and Spain began to mass their fleets and to rally their allies in preparation for war. An open breach was avoided by the Nootka Sound Convention, by which in 1792 Spain recognized the British right to trade and settle on those parts of the coast not already occupied. This convention recognized the parallel of 54°40′ as the southern limit of Russian territory.

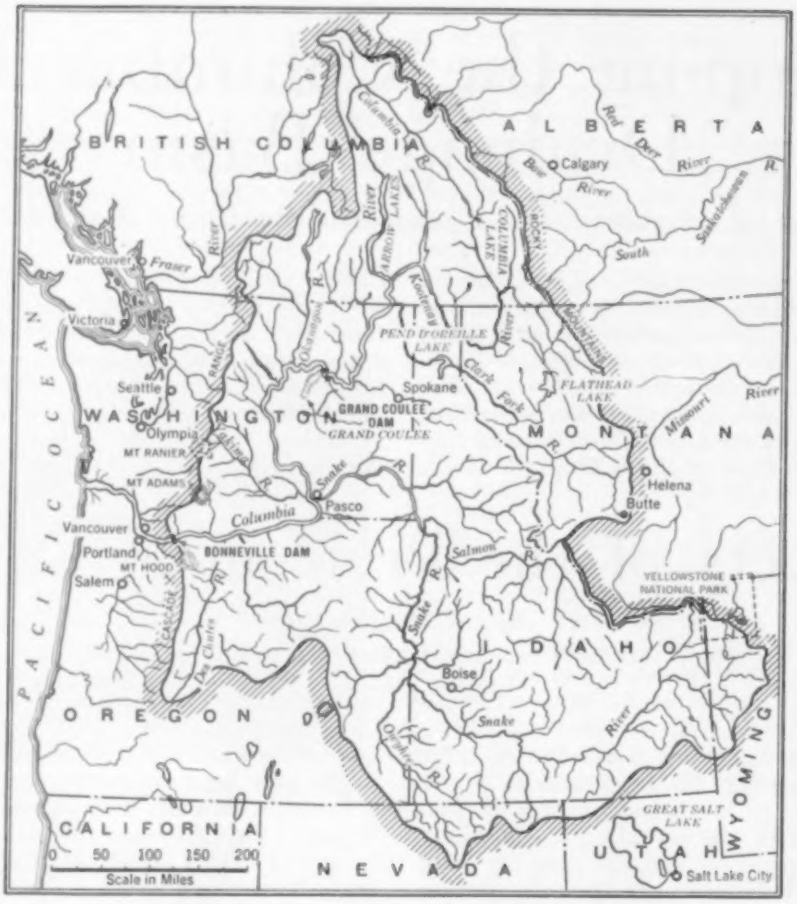


FIG. 1. THE COLUMBIA RIVER BASIN IN CANADA AND THE UNITED STATES

Then the Americans began to move westward, and in 1811 Astor's company, the Pacific Fur Company, established a post at Astoria at the mouth of the Columbia. Spain's hold was weakening. She was having her troubles in Europe and was no longer in a position to enforce her claims so far west. The more bleak and sparsely populated shores of the North Pacific did not furnish the rich harvest of loot she had gathered in the south, and in 1819, by the Florida Treaty, she relinquished her claims to all territory north of the 42d parallel. This left the United States and Great Britain as the only claimants on the coast between latitudes 42° and 54°40′.

Great Britain had never occupied, or been interested in the region south of the Columbia River. Therefore the dispute narrowed down to the ownership of the coast from the mouth of that river to the Russian boundary. In 1818 the 49th parallel had been adopted as the boundary from the Lake of the Woods to the "Stoney Mountains," but there the agreement stopped. Clauses of old treaties, discoveries, occupation and settlement, were all drawn into the argument, which was settled for the time being by a convention like that of Nootka Sound to the effect that the country with its harbors, bays, and creeks and the navigation of the rivers should be free and open to the subjects of both powers for a term of ten years. In 1827 this agreement was extended indefinitely, being terminable on 12 months' notice by either party.

Until 1846 the dispute continued, at times forgotten and at times forming the main topic of discussion in the American Congress and to a lesser extent in the British House of Commons. The British proposed an extension of the boundary along the 49th parallel to the Columbia River and thence to the coast along the center line of that river. The Americans stood out for the whole country up to "54-40."

As time went on, American settlements increased in what is now the State of Washington, and the British settlement on the Sound end of Vancouver Island grew in size and importance. Public feeling in the United States, excited by the slogan of the politicians, "54-40 or fight," became more intense. The British ships on the coast offered to settle the question in their own way. But for some years the saner heads on both sides had been favoring the extension of the boundary along the 49th parallel, with a deviation around the southern end of Vancouver Island. In 1846 one proposed it, the other at once accepted it, and the question was settled.

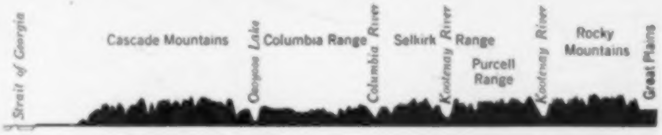


FIG. 2. A SECTION ALONG THE INTERNATIONAL BOUNDARY

It must be remembered that during all this discussion California was in the hands of the Spaniards. There was not one good harbor between the Spanish territory and Puget Sound. The British never seriously viewed the country as a settlement project; it was too remote, and the part of it they knew was too rugged to interest them. They wanted an outlet on the Pacific Ocean, the nearer to China the better.

Had the Americans had access to the port of San Francisco and the British a true appreciation of the great wealth of the land, the Columbia River might have been the boundary between the two nations, and a real problem would have resulted—another St. Lawrence River problem. But fortunately that is all behind.

Negotiation and its attendant ill feeling are past, and our present problem is one of cooperation to secure the maximum benefits to the people of both countries.

General Description of a Great River System

The watershed of the Columbia and its tributaries in British Columbia comprises just over 40,000 sq miles and lies entirely within the North American cordillera between the 49th and 53d parallels of latitude. A glance at the cross section of the country as prepared by the Canadian Geological Survey (Fig. 2), is sufficient to give an appreciation of its general character.

Only about 15 sq miles in the entire area lie under the 1,000-ft contour. Narrow valleys among the mountain peaks contain the only land suitable for human habitation. Roughly 8,000 sq miles lie between the 1,000 ft and 4,000-ft contours. Only about 310 sq miles, or 200,000 acres, are suitable for cultivation. About half the population of 78,000 is engaged in agriculture and half in mining, besides some few in lumbering. The precipitation varies from 65 in. on the summits of the Selkirks to under 20 in. in the valleys. The valleys and adjacent benches are fertile and, where irrigation water is available, very productive.

The area is estimated to contain 13,800,000,000 ft of accessible merchantable timber. Of this, from 250 to 300 million ft are cut in a normal year, giving employment to about 2,000 men. Up to the present, transportation difficulties have prevented the manufacture of pulp and paper.

Mining has been the main industry in the area. Many of the tributary streams carry placer gold and have been worked spasmodically since 1863. Large deposits of high-grade coal occur in the Crowsnest Pass and at

Upstream Side of Corra Linn Plant, Kootenay River, Canada

Princeton and Coalmont and have been mined continuously for many years. The recent general slump in the coal mining industry has had its effect in these localities. Lode gold mining, which is carried on all over the area, has been stimulated recently by the increased price of that metal. Metal mining has been and probably will continue to be the main industry in the Columbia basin.

The main stream of the Columbia River has its source in Columbia Lake, which lies at an elevation of 2,650 ft, in the great trough between the Rocky and Selkirk mountains just north of the 50th degree of latitude. The mountains on either side of the narrow valley rise to a height of 11,000 ft. At its source, the river drains the east slope of the Selkirks, the drainage from the Rockies being cut off by its tributary, the Kootenay. The river flows in a northwesterly direction on an easy grade through the beautiful Windermer Lake to Golden Lake just north of latitude 51. Here its moderate flow is increased by that of the Spillimacheen River from the Selkirks, and the Kicking Horse, which brings in the first of the Rocky Mountain drainage. The character of the stream changes. It flows through a series of canyons and rapids unbroken save for a short stretch through Kinbasket Lake. At Boat Encampment,

Okanagan Lake, Penticton, British Columbia

just north of the 52d parallel, it is joined by the Canoe River from the north and turns abruptly south between the Selkirk and the Monashee ranges. It continues its turbulent course to Revelstoke through a narrow valley with mountains rising over 10,000 ft on each side.

Between Golden and Revelstoke the river drops 1,130 ft in 180 miles. Here the profile flattens out. It falls only 40 ft in the next 30 miles, and in flood spreads itself over what might otherwise be a fertile valley. At Arrowhead it widens and deepens into the Arrow Lakes, which extend with a minor restriction to Castlegar, about 25 miles north of the boundary. Here it is joined by the Kootenay. It becomes swifter and drops 70 ft in 28 miles, being joined almost at the boundary by the Pend d'Oreille or Clark's Fork. A profile of the Columbia, the Kootenay, and the Pend d'Oreille rivers in Canada is shown in Fig. 3.

As would be expected from the character of the country drained, the Columbia is a very flashy stream, having its major discharge in the summer and its minimum flow during the late winter. The lakes of the main system have very little regulatory effect. Columbia and Windermere lakes are too small and too near the source to be of any value. Arrow Lake is 110 miles long, but very narrow—not much more than a widening and deepening of the river. The natural storage is almost negligible.

A maximum flow of 451,000 cu ft per sec at the international boundary was measured in June 1913. The lowest flow at the boundary since records have been kept was close to 17,500 cu ft per sec. The phenomenal runoff of 1894, before any records were established, greatly exceeded the 1913 maximum, probably to the extent of 50 per cent.

With its tributaries and lakes, the Columbia River played an important part as a transportation route in the early development of the Kootenay country. The possibility of moving machinery, ore, and concentrates of the base metals brought into existence the lode mining industry, which has been the main activity of the district. Palatial steamers of the type so well known on the Mississippi, and quite comparable in their appointments to those famous vessels, plied the waters of the Kootenay, Arrow, Slocan, and Okanagan lakes. During the nineties short railway lines were built along the shores of the faster stretches of the river from Nelson to Robson, from Revelstoke to Arrowhead, and from Kuskanook to Porthill. The smaller craft then disappeared.

Now, however, navigation on the Columbia system in Canada is dead; only some major economic change could revive it. The few remaining steamers are temporary links in the railway and highway systems.

As regards irrigation the case is different. A very large percentage of the irrigated land in British Columbia lies

KALEDEN ORCHARDS IN THE OKANAGAN VALLEY, PENTICTON, B.C.

in the Columbia Basin. Organized irrigation as a means of stimulating land sales began in the interior of British Columbia about 1900. Some of the early promoters received prompt and handsome dividends, and as a consequence by 1910 some 15 or 20 companies were selling irrigated land in the dry belt of British Columbia. About 1914 the water users began to realize that the companies could not be relied on for the replacement of the perishable part of the works and that there was grave danger that before long the supply to their lands and orchards, which were then becoming valuable, would cease. They approached the government for some assurance of protection or assistance. In 1920 legislative provisions were made for the organization of irrigation districts, and thereafter the necessary funds were loaned to these districts. The funds necessary for the acquisition and reconstruction of the systems were advanced by the Provincial Government. In 1921 the first payments from the districts were demanded and promptly met. The payments due in 1922 were met before it was recognized that there was a serious collapse in the market for agricultural produce. In that year the growers received practically no returns for their produce, and the users within the irrigation districts were very seriously affected.

As a result of the importunities of the growers, the government declared a two-year moratorium on irrigation loans. Thus the irrigation problem definitely entered the political field. The moratorium was continued for another two years, and since that time the problem has never left the doorstep of the Parliament buildings.

Since the capital cost of the irrigation developments is high, in some cases approaching $150 per acre, only intensive cultivation and high-priced crops, such as fruit and truck, can pay the resultant costs. Unfortunately, only a part of the land is suitable for such produce. The seasons are relatively late so that the various varieties of fruit reach the market too late to bring the best prices.

There is only one government owned and operated irrigation project in the Province of British Columbia. This is in the Okanagan Valley just north of the international boundary. It was started in 1919 in response to a post-War demand for employment and land for soldier settlers. To date only about 30 per cent of the land has been taken up. There have been several adjustments of prices and terms of payment, and the settlers are demanding further concessions.

On the Canadian side the main interest in the Columbia River lies in its power potentialities. Plants with an installed capacity of 259,000 hp are at present in operation on the river and its tributaries. According to present information, the system is able to provide a total of 803,400 continuous, and 1,348,000 seasonal horsepower.

On a stream with as wide a fluctuation in flow as the Columbia River, the storage of flood water for the purpose of increasing the low-water flow is all-important from the power standpoint. The maximum economic development of the stream is governed by a number of factors, of which the basic one is minimum flow. Navigation as well is usually benefited by regulation.

The area of the lakes on the Columbia system in Canada is small compared to the total drainage area, and consequently complete regulation of flow is quite impossible, but sufficient storage can be economically developed materially to increase the power capacity of the river. It is in this connection that the greatest opportunity for international cooperation lies.

By an arrangement that has been in force since 1913,

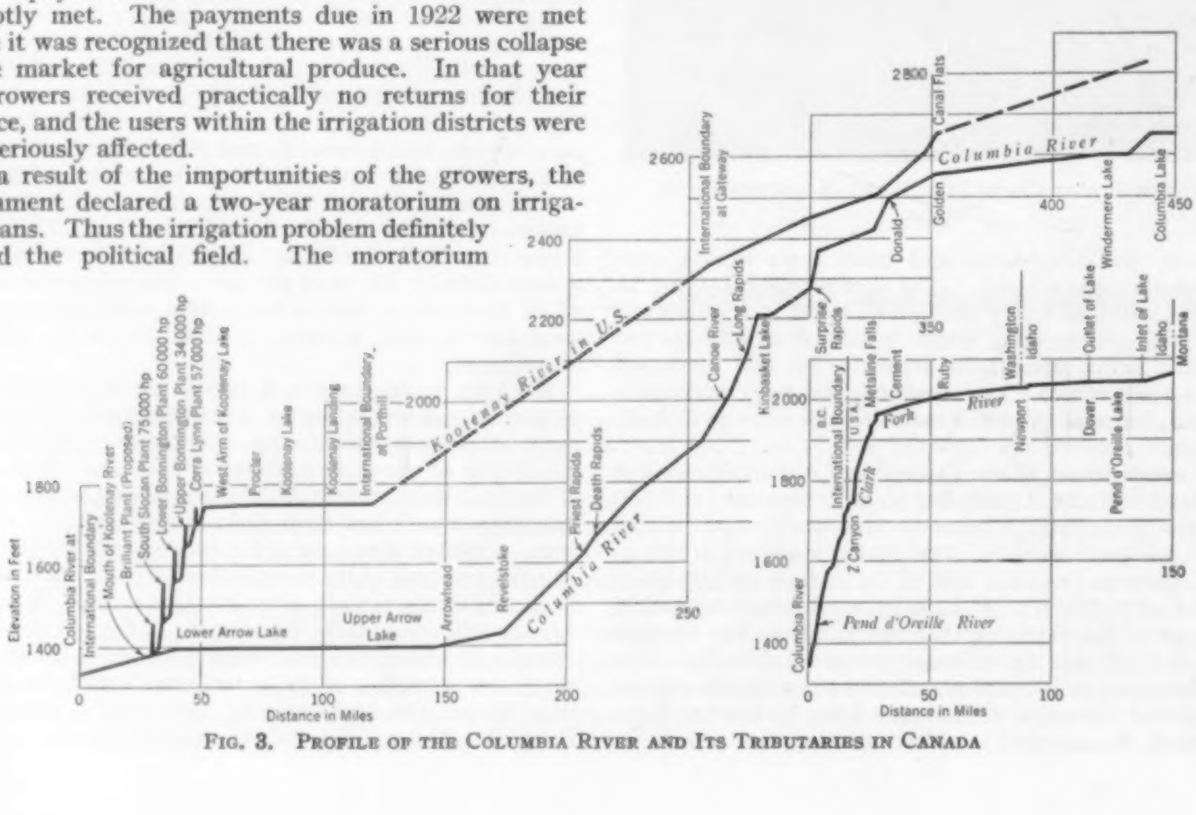


FIG. 3. PROFILE OF THE COLUMBIA RIVER AND ITS TRIBUTARIES IN CANADA

all hydrometric work in British Columbia is done by the Dominion Water Power and Hydrometric Bureau. It may be of interest to those who are associated with the development of the river south of the boundary to know that the Government of British Columbia is initiating a series of snow surveys, on the Nevada system, and is establishing ranges at the headwaters of the Columbia and Kootenay rivers. The area is not one that lends itself to accuracy of prediction from snow data, but it is hoped that within a few years seasonal records will be available which will be of material assistance in estimating the total run-off.

The various parties interested in the Columbia River on the two sides of the line should make the most of every opportunity to become better acquainted. It might be of advantage for them to get together in a semi-formal way for the specific purpose of promoting a co-operation that will be of advantage to both countries.

Power and Navigation Below the Snake River

By C. F. Williams
Corps of Engineers, District Engineer, Portland, Ore.

The Columbia River from the Snake River to its mouth flows a distance of about 325 miles. In this stretch it is comparatively straight as rivers run, as evidenced by comparison with the air-line distance between the two points, which is about 240 miles. This stretch of the river may conveniently be divided into tidal and non-tidal sections. The former, which has a length of 145 miles, extends upstream to approximately the Bonneville Dam site; and the latter, beginning there, has a length of 180 miles and a rise of 305 ft, or an average slope of 1.7 ft per mile.

In its course to the sea, the river has cut through both the Cascade Mountains and the Coast Range. Between these it traverses an area consisting partly of lowlands, including the Willamette Valley in Oregon and the Cowlitz Valley in Washington (Fig. 1). East of the Cascades it has eroded a canyon of varying depth and width in the basalt formation resulting from the great lava flows of eastern Oregon and Washington.

THE TIDAL SECTION

Its combined watershed area at the mouth of the Snake River is 212,000 sq miles. Below the mouth of the Snake, the combined additional tributary watershed is 47,000 sq miles. The mean annual flow at Bonneville for the period 1878–1933 was 210,000 cu ft per sec. The lowest year produced about 60 per cent of the mean, and the highest, 155 per cent. The maximum flood flow of record at this point is 1,170,000 cu ft per sec in June 1894, and the minimum, 40,000 cu ft per sec in January 1930.

At the mouth of the river the tidal heights vary from a maximum of about 12 ft above, to a minimum of about 2.5 ft below mean lower low water. The tidal range averages about 8 ft. At Portland, Ore., little or no tidal range is noticeable when the river stage is above 10 ft. At low stages in the river the average range is about $2^1/_2$ ft. The tidal flow is of course affected by the range of the tides and the amount of discharge from the river itself.

Two rubble-mound jetties have been constructed at the mouth of the river. The south jetty, about 7 miles long, required about 5 million tons of stone for its construction. The north jetty, about $2^1/_2$ miles long, contains about 2,743,000 tons of stone. The ends of the jetties are 2 miles apart. This work was completed in 1918 and has cost approximately $14,000,000. These jetties have succeeded in providing and maintaining a depth of 45 ft over the ocean bar without the aid of dredging. At present the south jetty is being retopped to a height of 26 ft above mean lower low water. This work, when completed, will have required about 2,000,000 tons of additional stone.

The present project provides for an inner channel 35 ft deep and 500 ft wide from the mouth of the Columbia to the mouth of the Willamette River, a distance of 99 miles, and thence up the Willamette to Portland about 14 miles; a channel 28 ft deep and 300 ft wide in the Columbia from the mouth of the Willamette to Vancouver, Wash., $4^1/_2$ miles; and other auxiliary channels. The improvement of these channels has been effected by the construction of stone and pile dikes and revetment as well as extensive dredging. Systems of pervious dikes have been very effective in reducing maintenance dredging.

All initial dredging and dike construction under the project were completed in 1933 at a total cost of about $4,900,000. Maintenance dredging of the inner channel is carried on throughout each year. In the estuary and on some of the bars on the lower river hopper dredges are used. In the upper river the work is performed with pipe-line dredges. This work is done principally by Government dredges, some by contract. Under a rental agreement with the Port of Portland, its two dredges have been used for short periods. The total maintenance cost, including both dredging and repairs to the dike, has amounted to about $8,000,000.

This important artery of commerce averages 6,600,000 tons per annum, valued at $300,000,000 in intercoastal and foreign trade. An equal tonnage, although it is of less value, moves between ports on the river.

NON-TIDAL SECTION

The non-tidal section of the river is a series of pools and rapids. There are two principal rapids, the first extending from the Bonneville Dam site to the head of the Cascade locks, where there is a fall of 35 ft in a distance of four miles, and the second extending from The Dalles to the head of Celilo Falls, where there is a fall of 82 ft in 11 miles.

In years past numerous dam sites have been investigated below the mouth of the Snake by both the Federal Government and private interests, the most comprehensive study being that submitted by the District Engineer at Portland in 1931, in accordance with the provisions of House Document 308, 69th Congress, 1st session. Above The Dalles, where in many places the river is flowing on basalt, the selection of good foundations has not been particularly difficult. On the other hand, the location of a suitable foundation for a dam at or near tidewater has been a very difficult problem, because in this stretch the ancient river channel has subsided and the river has changed its course many times as a result of gigantic slides or upheavals. Extensive borings have failed to locate bedrock at depths permissible for a dam

foundation anywhere below Bonneville. Foundations have been found to be better at this site than at the head of the rapids, where a dam could be founded on a tuffaceous rock of moderate strength, known as Eagle Creek formation. At Bonneville the dam is founded on the Eagle Creek formation, and the lock and power house on basalt. The practical height of the dam is limited both by the available foundation material and by economic considerations, including the cost of flowage.

At The Dalles site, at the upper end of the Bonneville pool, foundation conditions would permit the construction of a dam of sufficient height to back the water up to the mouth of the Snake. However, considerations of economics, influenced greatly by flowage costs and carrying charges on one high dam, led to the selection of three dams for the complete canalization of this section of the river, at sites known as The Dalles, the John Day Rapids, and the Umatilla Rapids. The most important developments affecting flowage cost are the railroads and highways on both sides of the river. In Table I

TABLE I. PROPOSED DAMS ON THE COLUMBIA RIVER BELOW THE SNAKE

Site	Distance Above Mouth In Miles	Maximum Height In Ft	Useful Storage Thousands of Acre-Ft	Flow 90% of Time Thousands of Cu Ft per Sec	Corresponding Head In Ft	Power* Capacity 90% of Time Thousands of Kw
Umatilla Rapids	292	104	135	66.0	71	318
John Day Rapids	216	159	245	66.0	108	485
The Dalles	192	260	80	70.7	75	360
Bonneville	143	130	100	74.0	60	300

* Flow 90 per cent of time) × (corresponding head) × 0.068.

data are given relating to the four dams proposed for developing the river below the Snake.

In its present state of improvement the non tidal section of the Columbia is navigable at low water for boats of 5-ft draft to the mouth of the Snake River. Navigation above The Dalles is difficult because of swift currents, and somewhat hazardous owing to narrow, rocky channels through some of the rapids. The Cascade and Celilo Rapids are passed by lateral canals with locks. The vessels in operation are stern-wheel steamers, which sometimes tow one or two loaded barges downstream. The tonnage in 1933 was about 90,000 tons, all between The Dalles and points below.

BONNEVILLE DAM PROJECT

As now authorized, at an estimated cost of $31,000,000, the Bonneville project (Fig. 4) provides for a gate-controlled spillway dam across the main river channel, creating a head of 67 ft at low water; a power plant with two complete units of 43,000-kw capacity each, with partially completed or skeleton structure for four additional units; a barge lock having a width of 76 ft, a clear length of 360 ft, and a minimum depth of 10 ft on the sills; and fishways in both the dam and power house channels. The power house is being constructed across Bradford Slough so that it can be extended in the future to permit a total installation of 10 or even 12 units of 43,000-kw capacity each. The lock, also in Bradford Slough, which is being constructed as a single chamber of unprecedented lift, is so designed that it may in the future be used as an integral part of a tandem-lift ship lock. The gross head at the power plant will be 67 ft at low water; 40 ft at 750,000, the ordinary flood crest; and 23 ft for a discharge equal to that of the 1894 flood, which has an estimated frequency of once in 400 years.

The pool formed by the dam will have a length of 48 miles, a minimum depth of over 30 ft, and an area of 30 sq miles. It is expected that by providing liberal capacity in the spillway gates, and removing obstructive rock ledges in the rapids section just above the dam, the maximum flood height will not be raised by the dam in the stretch above the head of the Cascade Rapids.

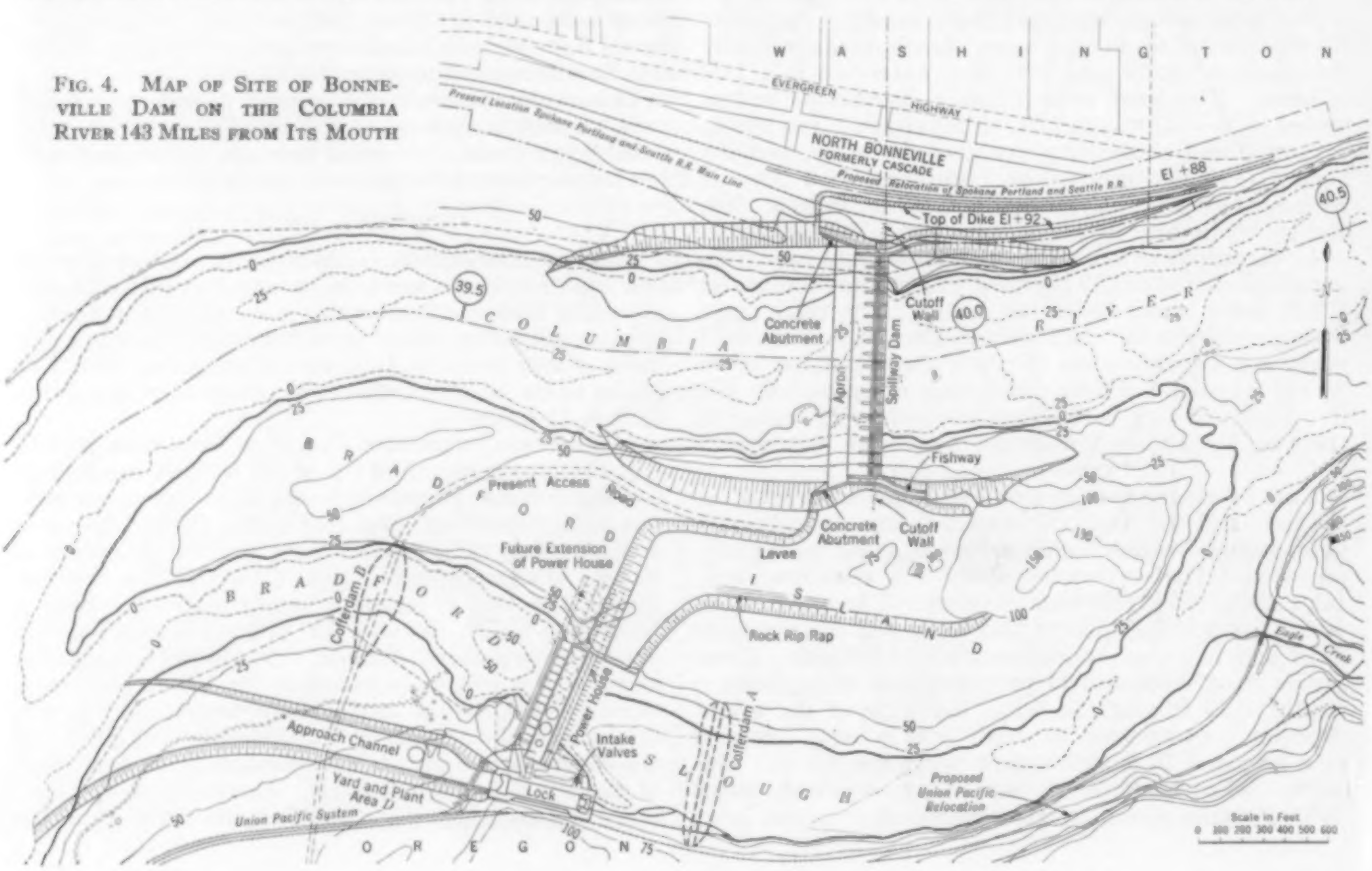


FIG. 4. MAP OF SITE OF BONNEVILLE DAM ON THE COLUMBIA RIVER 143 MILES FROM ITS MOUTH

In the main channel, the spillway dam (Fig. 5) is to be an overflow, gravity-type structure, consisting essentially of a base block of mass concrete approximately 75 ft high, 180 ft wide, and 1,100 ft long across the river, surmounted by tall piers and abutment walls enclosing 18 steel gates, each 50 ft wide by 50 ft high. The gates will be of the vertical-lift type and will be divided into upper and lower halves in order to facilitate erection and operation. The fixed crest or gate sill is to be at elevation +24; the foundations of the dam mass are to extend down to as low as elevation −76; and the surface of the pool will be at elevation +72. A concrete-encased steel truss bridge with a deck at elevation +97 will be built across the tops of the piers to serve the cranes that lift the gates.

ABUTMENTS AND CUT-OFF WALLS

A reinforced concrete abutment structure at each end will contain space for transformer vaults and control rooms for the electrical machinery required as well as a system of conduits and gates for the fishways. A reinforced concrete cut-off wall, reaching from the ground surface into bedrock or an impervious stratum, will extend well into each bank. The stream flow at the dam will be guided through the gates by upstream and downstream wing walls 230 ft long, of reinforced concrete construction. The upstream wing walls will carry canals leading to the fishways. As the proposed surface of the pool is at the approximate top of the existing river bank, short levees of rolled earth fill will connect the dam, on the Washington shore, to high ground, and on the Bradford Island shore, to the power house.

At the dam the principal engineering problems are the

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Mouth of the Columbia River

unusual volume of flood water to be safely passed, the comparatively soft rock available for the foundation, the large-scale river diversion, and the construction and unwatering of the cofferdams. On account of the requirement of passing and regulating a large flow, one of the principal problems in connection with the design of the dam was the provision of adequate and easily operated gates. This was met by the selection of eighteen 50 by 50-ft vertical-lift gates, equal in size to the largest yet built, which will be operated by either of two gantry cranes.

The passage of such large flows through a 900-ft opening presents an unusual problem in the safe destruction of energy. This is being met by so designing the overflow section as to ensure the formation of a satisfactory hydraulic jump on the deck of the dam. Baffle sills will be required to attain the desired results.

A gray-blue deposit of volcanic ash and rock fragments of all sizes constitutes the rock on which the dam will be

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Celilo Falls and Locks—The Dalles Dam Site, Looking Upstream

built. It was laid down before the outpourings of lava which later covered this entire region to depths of several thousand feet. The dam has been designed to load the foundation lightly, 110 lb per sq in. being the heaviest direct load on the structure considered as a whole. A considerable breadth of the foundation rock is interlocked with the concrete mass by means of steps to provide an estimated minimum factor of safety in horizontal shear of 12. The computed sliding tangent, based on the weight, horizontal thrust, and full uplift exerted on four-tenths of the foundation area, is 0.26. The foundation rock is to be further protected by a heavily reinforced concrete apron 5 ft thick, extending a distance of 100 ft downstream from the dam block.

METHOD OF RIVER DIVERSION PLANNED

As regards quantity and depth of water, and velocity of current, the task of river diversion and cofferdamming for the construction of the dam is believed to be the largest of its kind yet attempted. On account of the annual summer flood, the working season in the river is limited to approximately 8 months, August to March, inclusive. According to the plan that has been worked out for unwatering the dam site, a line of box crib cofferdams, sheeted on the outside with steel piles, will be constructed to enclose the south half of the site; half of the dam site will be unwatered and that part of the structure built within the enclosure; then the cofferdam will be removed and, after the summer flood has passed, the operation will be repeated in the north half of the channel.

During the construction of the south half of the dam the entire flow will be diverted through the north half of the channel, enlarged by excavating the north bank to the final channel outlines, and through the power house foundation in Bradford Slough. During the construction of the north half of the dam, the low-water river flow will be diverted through Bradford Slough and through the south half of the dam, in which the sills between piers will have been left at elevation −5 to facilitate this diversion. Final closure of the diversion slots

will be made individually by use of the permanent gates lowered through guides extended to the bottom of the diversion slots to cut off the flow. Each diversion slot will then be concreted to full height within temporarily installed cofferdams.

SINGLE-LIFT LOCK PROJECTED

Precedent in the design of a navigation structure with a maximum lift of 67 ft would dictate a double-lift or tandem lock. Foundation conditions at the Bonneville lock site would, however, require expensive construction for such a lock. A sill of andesite crosses Bradford Slough at the lock site but is not wide enough to accommodate a tandem lock. Part of such a structure would therefore have to be of simple concrete construction on rock foundation and part of reinforced concrete resting on gravel. Therefore an investigation was made to determine if there were sufficient rock foundation to build a single-lift lock. Core borings showed definitely that a single-lift chamber could be founded entirely on rock, and designs were made accordingly. The maximum lift will be 67 ft at low water, the normal lift, 59 ft, and the lift at high water, 47 ft.

Three floating mooring bitts will be provided in each wall of the lock. These consist of a vertical post protruding from a floating steel plate chamber, which is recessed in the lock wall. In operation, a boat is tied to the post, which rises or falls with it when making a lockage, eliminating the necessity of changing lines from one fixed hook to another as the water level changes. Floating mooring bitts have been used experimentally at the Lake Washington lock at Seattle and were recently constructed at the Dniepostroy locks on the Dnieper River, Russia.

HYDRAULIC MODEL STUDIES

Studies of models in operation form an important part of the design program for the Bonneville Dam. Full advantage is being taken of the possibilities inherent in this method of checking the hydraulic designs as well as studying and improving those features not readily amenable to mathematical analysis. Model studies for the dam center around the choice of a spillway-deck and baffle-sill combination best suited to the maintenance of a stable hydraulic jump over the range of flows and combinations of gate operation required. The problem is complicated by a possible range of 60 ft in tailwater elevation and by the desire to operate a central group of gates to care for all minor fluctuations in flow in order to maintain near the abutments the most desirable flow conditions for trapping fish and transporting them safely over the dam. Experience to date with the model has developed two satisfactory spillway cross sections, but experiments are being continued in an effort to secure a flow with minimum surface turbulence and maximum structural economy.

Backwater caused by the dam requires careful consideration inasmuch as many improvements have been constructed along the shores of the lake extending 40 miles from the Cascade Locks to The Dalles. For the most part these improvements have been built, as regards elevation, to allow only for anticipated flood heights under natural conditions.

Extensive backwater studies have been made of the Cascade Rapids and also of the pool above the Cascade Locks. The backwater calculations in the Cascade Rapids have been made with unusual care and accuracy and will be checked by flow experiments on a 1:100 natural scale model of the rapids. In order to increase the channel capacity between the dam site and the Cascade Locks, channel rectification work is planned. This will first be checked in the natural scale model. All the hydraulic model studies, except those on the draft tubes, are being conducted at a hydraulic laboratory set up for this project at Linnton, near Portland, Ore.

Fishway designs for the dam have been prepared both for a ladder of the conventional type, although of somewhat heroic dimensions, and for a hydraulic lift operated in conjunction with a floating trap. In both designs fish are attracted by means of outflow over a weir, into a passage contained on a floating barge moored immediately below the closed gates, near the sides of the dam.

Swimming against the current, the fish are attracted either into the ladder or into a hydraulic lift in which at intervals the entrance gates are closed and water admitted to raise the fish to the upper

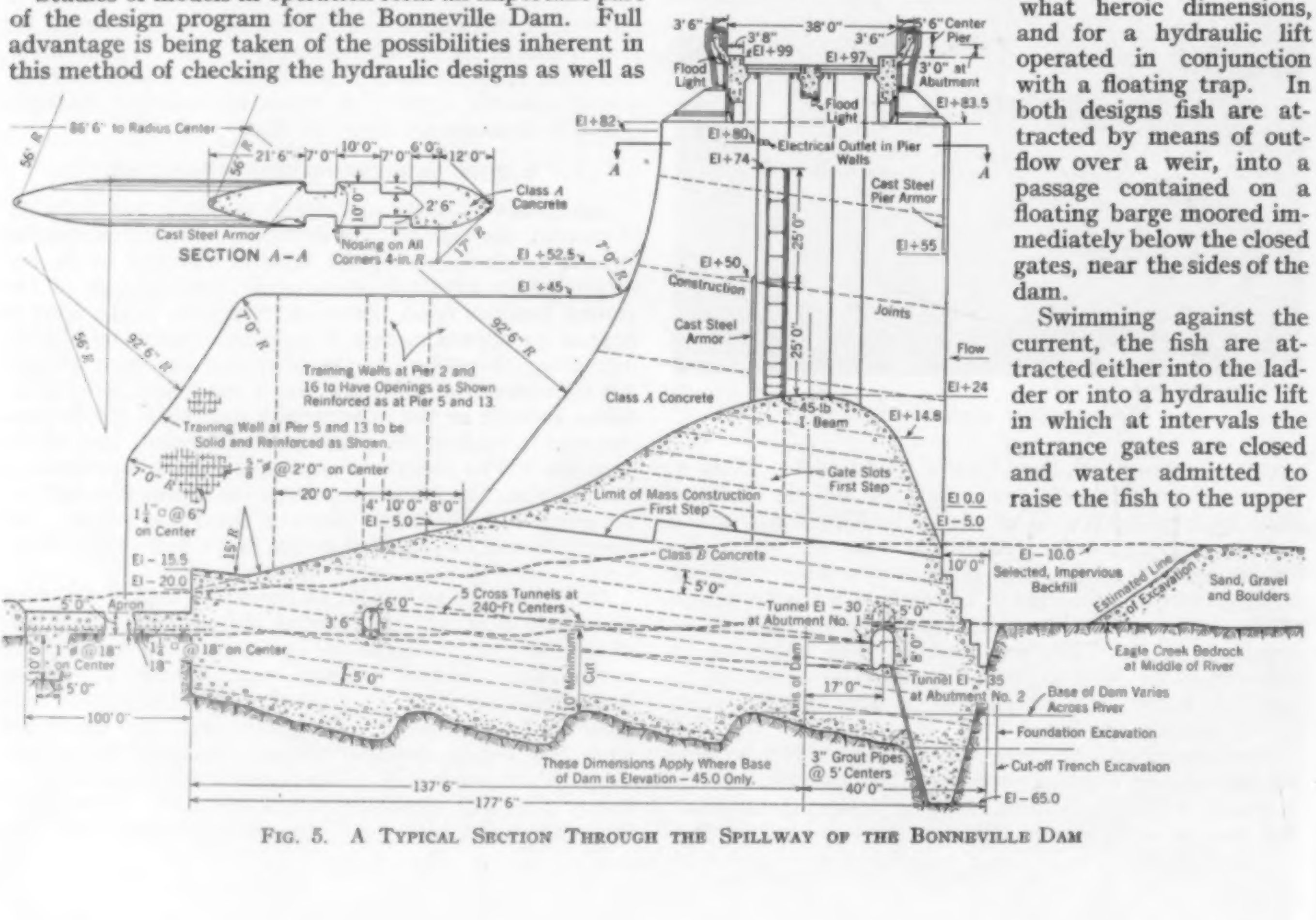

FIG. 5. A TYPICAL SECTION THROUGH THE SPILLWAY OF THE BONNEVILLE DAM

level, where they are discharged. This device is a modification of that at the Ariel Dam on the Lewis River, where marked success in fish handling has been attained. Fish lifts have been designed for use at the south end of the power house. The lock is also designed for use in passing fish. In addition, the fish will be trapped along the downstream side of the power house in either a fixed or floating trough and led to the lifts and the locks.

RAIL AND HIGHWAY RECONSTRUCTION

Throughout the length of the pool, the river canyon is traversed by two transcontinental railroads and two major state highways: the Oregon-Washington Railroad and Navigation Company's line (the Union Pacific) and the Columbia River Highway on the Oregon side; and the Spokane, Portland and Seattle Railway and the Evergreen Highway on the Washington side. The Spokane, Portland and Seattle Railway was constructed throughout at an elevation above the flood of 1894. Therefore, except for a maximum rise of about 7 ft opposite the dam, it requires only the adjustment of submerged drainage openings and bank protection by riprap to make it safe with the heightened water levels.

The reconstruction of the railroad on the Oregon side is a more difficult problem, since the present line was constructed on a much lower level and requires a rise in elevation opposite the dam of about 35 ft. The work to secure this elevation is to be started about 1.5 miles below the dam. Thence the railroad is to be supported on a 0.45 per cent grade on an independent alignment to the dam, from which point it will follow the grade of the backwater curve until it intersects with the present grade about 2.5 miles above the dam. This location involves crossing the face of Ruckel Slide, a stretch of about $1^1/_2$ miles of unstable terrain subject to landslides, which requires special treatment.

Neither of the highways presents a problem of any magnitude. They are generally at an elevation well above the backwater curve, although in a few places they occupy low ground, usually where there are intercepting creeks and side drainage. At such places it will be necessary to raise the grade, adjust the culverts, and protect the banks against the action of water.

Construction logically divides itself into a number of separate contracts, and it has been further subdivided to provide local employment as early as practicable, as well as to expedite the work as a whole. Except for certain minor items this project is being constructed by contract. By July 1, 1934, awards had been made for

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SITE OF BONNEVILLE DAM LOOKING DOWNSTREAM
Cascade Locks, Bridge of the Gods, and Bradford Island

construction and camp roads; temporary and permanent buildings; relocation of the Spokane, Portland and Seattle Railroad; the main spillway dam, except the gates; the lock, except gates and equipment; and the substructure of the power house.

As of July 1, 1934, the cost of work done or under contract amounted to about $16,000,000. It is contemplated that all work within cofferdams will be completed by April 1, 1937, and that the pool will be raised and the power plant ready for operation by December 31, 1937.

For their valuable assistance in the preparation of this paper, appreciation is here expressed to C. I. Grimm, M. Am. Soc. C.E., head engineer of the Bonneville Power-Navigation Project; to the heads of design sections under his charge; and to R. E. Hickson, in charge of the improvement of the Columbia River from Portland and Vancouver to the sea.

Bonneville Power House and Equipment

By B. E. Torpen
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SITUATED at the head of tidewater on the Columbia River, the Bonneville Project is 42 miles east of, and upstream from Portland, Ore. At the site, Bradford Island divides the river into two channels. The power house occupies the Oregon channel, which will act as forebay and tailrace. Above Bonneville the run-off from the melting snow of the mountains is partially regulated in the numerous large lakes on the headwaters and tributaries, such as Wenatchee, Chelan, Okanogan, the Arrow Lakes, Kootenay, Pend d'Oreille, Flathead, and Jackson Lake.

Several thousand cubic feet per second is diverted from flood flows for irrigation and is partially recovered months later in return flow. Floods from various districts and varying elevations are staggered so that the summer flood at Bonneville is usually not flashy but a sustained outpour over a period of a hundred days. With such volumes of water, storage reservoirs of normal capacity would have little regulating effect. Several of the large lakes may be utilized to store one or two million acre-feet each, but they are either required for future irrigation or their capacity is restricted by state law. The High Dam at the Grand Coulee may provide five million acre-feet for power regulation.

Other storage possibilities on the headwaters of the Columbia, the Snake, and their tributaries, together with return flow from irrigation, may ultimately reach a total of 10 or 12 million acre-feet useful for power. To fully regulate the Columbia over the 55 years of record, a storage of 450 million acre-feet would have been

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COFFERDAMS FOR POWER HOUSE IN PLACE
Bradford Island and Construction Camps Shown

required, and for the past 29 years, that of 200 million would have been necessary. Obviously, long-time

TABLE I. POWER OUTPUT OF THE BONNEVILLE PROJECT AT VARIOUS HEADS

Gross Head In Ft	Corresponding Flow in Columbia River Cu Ft per Sec	Percentage of Time This Flow Is Exceeded	Turbine Horsepower	Generator Kilowatts	Cu Ft per Sec Required per Unit
35	950,000	0.1	38,250	28,100	11,470
45	550,000	5.6	53,000	38,700	12,330
50	286,000	22.5	60,000	43,860	12,420
55	150,000	47.5	60,000	43,860	10,600
65	40,000	100	60,000	43,860	9,000

regulation can never be obtained. The ultimate storage of 12 million acre-feet useful for power would provide a minimum continuous flow of about 100,000 cu ft per sec at Bonneville, but this development lies so far in the future that it has not been considered an important factor in the present design.

POWER INSTALLATION AND PROJECTED OUTPUT

As authorized, the Bonneville Project consists of ten 43,000-kw generating units, of which only two are to be completed now. Water requirements and output at various heads are shown in Table I. In a normal year, with ten units installed, the power available will be about three billion kilowatthours at a load factor of 85 per cent.

As shown in Fig. 4, the power house structure will act as a dam across the south, or Bradford Slough channel of the Columbia. The exact location was determined by the position of a basalt sill across this channel, and the provision of an economical tailrace, together with a suitable location for the navigation locks on the Oregon shore.

Since the width of the south channel is about 500 ft, and the power units are spaced 82 ft apart on centers, only six are required to make the closure. The power house superstructure (Fig. 6) for the present will consist of a control room, an assembly bay, one 2,500-kw house unit, and two 43,200-kw main units. The intakes and skeleton substructures for four more main units will be constructed at this time to complete the dam across the south channel. The ultimate extension of the power house beyond this point is provided for by the present construction of a reinforced concrete cantilever wing wall about 120 ft high to retain the backfill and to act as a future cofferdam for unwatering footings for the ultimate installation of four or six more units.

In vertical cross section this wall is an inverted "T,"

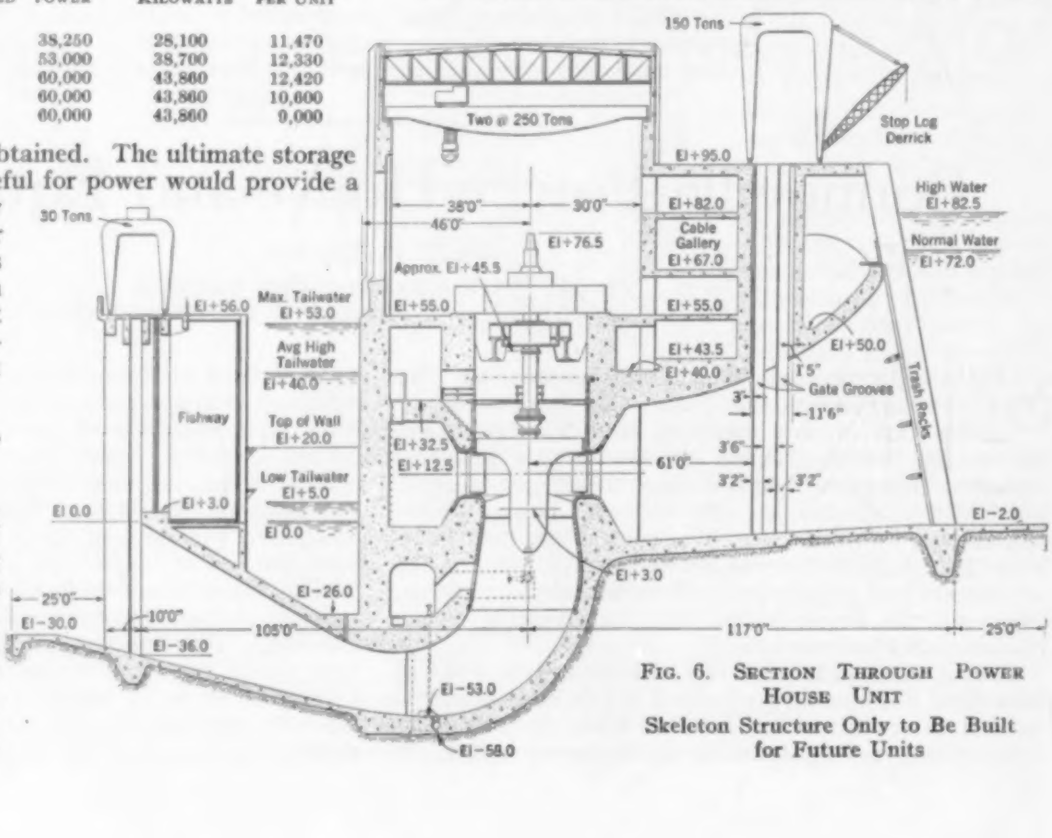


FIG. 6. SECTION THROUGH POWER HOUSE UNIT
Skeleton Structure Only to Be Built for Future Units

as shown in Fig. 7. It rests on basalt rock and depends on the water load for stability. The wall extends upstream from the intake piers for a distance of 160 ft. The design was selected from a number of alternates because the slender upright stem, 12 ft thick at the base and 3 ft thick at the top, lines up with a power house pier and may be left permanently in place, thus eliminating the heavy cost of removal under water.

Supporting the superstructure power units will be seven main piers 8 ft thick by 240 ft long and from 80 ft to 140 ft high. In each bay, two intermediate piers 5 ft thick, together with the headwalls, reduce the size of the gate openings to 21.33 by 43 ft. Three such gates are required for each unit. On the downstream side of the power house a single intermediate 6-ft pier divides the draft tubes into two 34-ft spans for closure by stop-logs during unwatering.

To install additional units it will be necessary only to place the downstream stop-logs, place structural steel struts between the piers, and pump out the substructure for one unit at a time. The unwatering pumps will consist of two units of 5,000-gpm capacity each, connected to an 18-in. cast-iron header pipe running lengthwise of the power house in a trench under the lowest point in the draft tubes.

STEEL HEADGATES, STOP-LOGS, AND CRANES

In the intake the openings will be closed by gates of conventional structural steel design. As there are three openings for each unit, there will be six gates for the two units now to be installed. Of these six, only two will be equipped with roller bearings enabling them to be raised against full head on one side when the scroll case is empty. However, any gate will be interchangeable with any other and may be placed in either of the two sets of grooves provided in each bay. Also, one of the headgates will be used, when required, to close off the house-unit bay. The gates will be handled by the gantry on the intake deck. Water-tightness will be secured by rubber strips, bearing against stainless steel rubbing plates. On the bottom there will be a metal-to-metal contact of a sealing plate resting on babbitt metal in a groove in the sill.

The gate wheels will run on hardened nickel-steel tracks attached to heavy structural guide members, which will distribute the loads over the concrete bearing area. The loads will finally be taken into the structure by means of reinforced concrete. The structural steel guides will be built into towers thoroughly cross-braced and sufficiently strong in themselves to preserve the alignment. Heavy removable steel templates spanning the distance from pier to pier will also be in place during the placing of the concrete. The 12 intake openings for the four skeleton structures of the future units will be closed off with reinforced concrete stop-logs.

An idea of the size of the Bonneville units is obtained by the consideration of some simple features, the draft-tube stop-logs, for instance. Were the conventional wooden timbers used, they would have to be about 7 ft thick. Thus wood is out of the question, and the stop-logs in effect will be structural steel gates divided into sections for reasonable ease in handling and storing. It is planned that bearing seats will be embedded in the concrete to take the load, but the seal for water-tightness will be made with rubber strips in contact with bronze sealing strips. The stop-log gates will be designed for the maximum expected flood, and so will make unwatering possible at any time. With maximum height of tailwater, there will be a head of 89 ft at the bottom.

Cranes will be required at three locations. Inside the building the heaviest load will be the generator rotor weighing 400 tons. It is planned to handle this with two 250-ton cranes and an equalizer beam. Each of the cranes will also have a 30-ton auxiliary. The cranes are not of unusual capacity, but the long lift requires so much cable that unusually large winding drums are needed. The clear span will be 70 ft. At the intake the gantry crane, of 150-ton capacity, will handle the gates, trash racks, regulating weirs of the trash sluice, and trash-rack raking devices. Downstream a small gantry of about 30 tons capacity will move the draft-tube stop-logs.

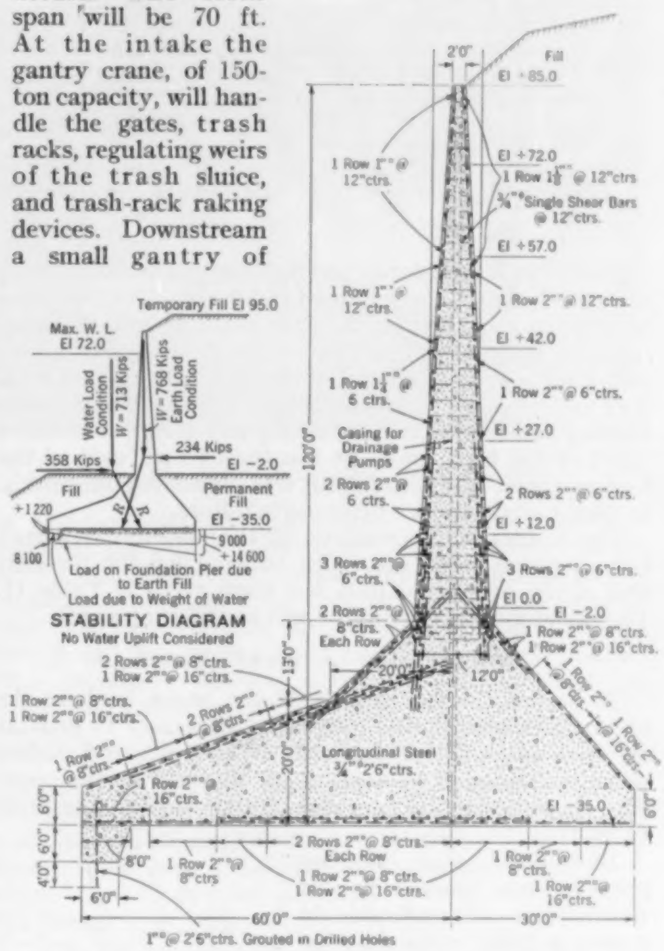


FIG. 7. POWER HOUSE WING WALL, BONNEVILLE DAM

Throughout the length of the power house structure the foundation rock is andesitic basalt with a crushing strength of 7,500 lb per sq in. and a shearing strength of from 2,000 to 3,000 lb per sq in. The surface of the foundation rock is very uneven and is overlaid by coarse river sand, gravel, and boulders in depths varying from zero to 100 ft. There will be an upstream cut-off trench 10 ft wide by 12 ft deep in solid rock, backfilled with concrete. In the bottom of this trench, 40-ft grout holes will be drilled on 10-ft centers and grouted with cement grout at a pressure of 100 lb per sq in. to ensure practical water-tightness. Immediately downstream from the basalt sill there is a deep pool extending down to elevation −75, giving a normal depth of water of about 100 ft. Discharge from the draft tubes will be into this deep pool.

DESIGN DATA FOR THE PROJECT

In the design of the reinforced concrete structures the following standards or assumptions were used:

Maximum allowable tension in reinforcing steel	18,000 lb per sq in.

Maximum allowable tension in structural steel	18,000 lb per sq in.
Maximum allowable compression in concrete	1,000 lb per sq in.
Minimum reinforcing steel for shrinkage in each direction	0.50 per cent of total cross section
Wind load on projected area	40 lb per sq ft
Allowance for ice thrust	none
Live load on power house operating floor	1,000 lb per sq ft
Live load on intake deck slab	1,000 lb per sq ft
Live load on power house roof, where not loaded	100 lb per sq ft
Strength of concrete at foundation, in shear (where W = weight of concrete structure + water and U = uplift)	400 lb per sq in. + $0.7W - U$

Under the intake apron and slab the hydraulic gradient of uplift pressure was assumed to be a straight line from headwater to tailwater at the point of full drainage relief. Uplift was measured to this hydraulic gradient and assumed as effective on 40 per cent of the area. The criterion of complete safety against initial overturning and final failure in sliding was that the effective uplift at the heel should be less than 40 per cent of the loading there. A greater uplift was considered dangerous, in that it might induce progressive failure.

The results of the analysis of the skeleton structure (where power units are to be omitted for the present) and of the completed unit No. 1 are given in Table II. The skeleton intake structure will be stable as a unit.

WATER LOAD ON INTAKE FLOOR

To secure the full benefit of the water load on the intake floor slab it was considered necessary to provide an open space under this slab so that it could deflect downward enough to transfer all the load to the piers. The space under the floor slab drains through the draft tubes.

The gate and stop-log grooves were placed as far downstream as practicable to ensure a large water load on the intake slab during unwatering operations. The value of the water load may be realized from the fact that about $20,000 worth of concrete per unit would be required to give equal stability.

To provide for the sure and safe passage of salmon an elaborate pick-up system extending across the structure for six units, with lifts at the south end, has been designed. The water requirements for the initial fishways at the power house will be relatively low during low flow, as few salmon migrate then. A similar installation will be made for the four future units, when constructed, if it is found desirable.

For variations in head and load, the power house turbines will be of the Kaplan type with blades automatically adjustable. Extreme variations in head may be from 20 to 70 ft. A characteristic of this type of turbine is its high efficiency over a wide range of head and load. In physical size the units will not be the largest built, but in operating head, quantity of water required, and power output, they will rank with the largest, as seen from Table III.

TABLE II. FORCES AND STRESSES IN POWER HOUSE STRUCTURE
Skeleton Structures and Completed Units Pumped Out

ITEM	SKELETON STRUCTURE, HEADWATER AT +72	COMPLETED UNIT, HEADWATER AT +72 AND TAILWATER AT +5
Sum of all horizontal forces, in kips	28,800	10,500
Sum of all vertical forces, in kips	60,500* = W	83,700 = W
25 per cent uplift force, in kips	500 = U	6,100 = U
Sliding tangent on horizontal plane	0.48	0.14
Horizontal shear (lb per sq in.)	70	26
Safe shear (lb per sq in.)	530	501
Safety in shear	7.6	19
Heel pressure (lb per sq ft)	11,600	11,800
Toe pressure (lb per sq ft)	28,200	38,800

* Not including uplift.

The turbines will be designed for 60,000 hp at a 50-ft head, for 75 rpm, and for 85 per cent efficiency. Under these conditions each unit will require only 12,200 cu ft per sec. As the flow in the Columbia at Bonneville corresponding to this head is 286,000 cu ft per sec, more than half the available water must be wasted. However, economy in the use of water is not important at such periods. A flow of 286,000 cu ft per sec is exceeded 22.5 per cent of the time.

When the flow falls to 75,000 cu ft per sec of water or less, which happens only 7.5 per cent of the time, the gross head increases to 60 ft or more because of lowered tailwater elevation. The efficiency at 60,000 hp at a 60-ft head is 90 per cent, and a flow of only 9,650 cu ft per sec of water is required. The efficiency at a 60-ft head is maintained at about 90 per cent for outputs varying from 60,000 hp down to about 35,000

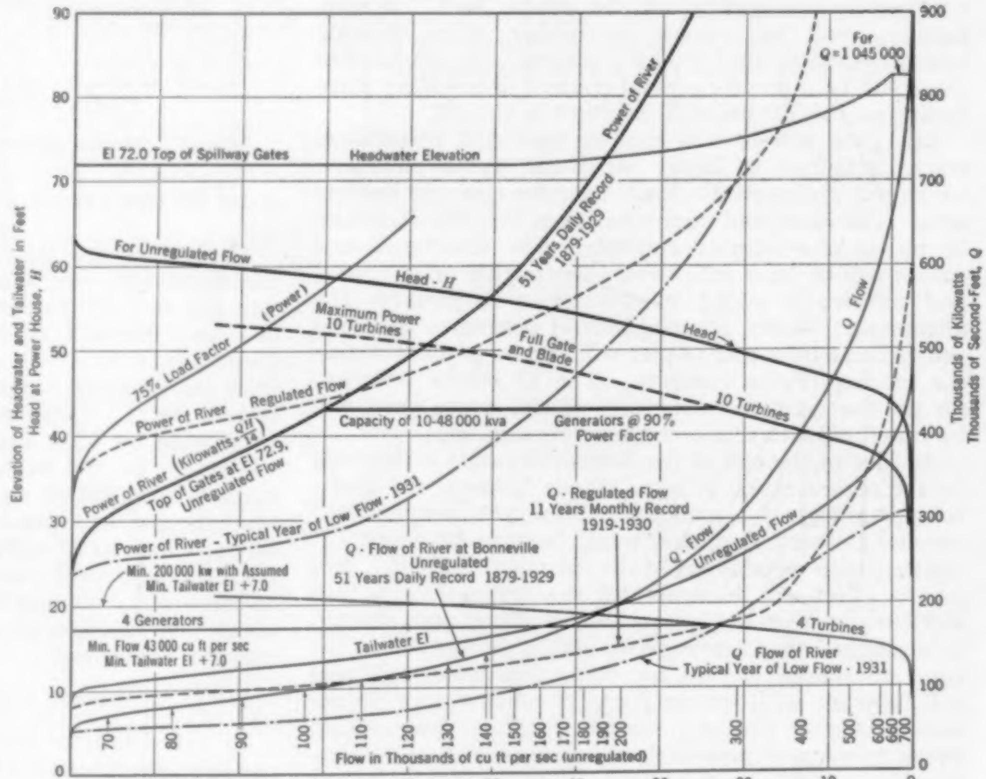


FIG. 8. CURVES OF FLOW, POWER, AND EFFICIENCY FOR BONNEVILLE POWER PLANT

hp by the automatically adjustable blades and gates of the Kaplan turbine. For other heads similar characteristics prevail.

Some features of the design are: renewable throat rings, special chromium-nickel surfaces on turbine blades, very high governor-oil operating pressures (300 lb per sq in.), and twin governor-oil pumping system. The diameter of the hubs will be 8 ft, that of the draft tubes, 23 ft, and that of the scroll case, 72 ft. About 12,500 cu ft per sec of water will be the maximum required for each unit.

TESTS OF SCROLL CASE AND DRAFT TUBE

Tests on small models of scroll cases and draft tubes are being conducted to determine the most efficient types. Later, tests with a 16-in. model runner will be made at the Holtwood, Pa., or the manufacturer's laboratory before final selection of the design of scroll cases and draft tubes.

The rating of the 3-phase, 60-cycle generators will probably be about 43,200 kw at 13,800 v. They will be of the conventional umbrella type with direct-connected exciter and pilot exciter. Cooling will be effected through the use of surface coolers in an enclosed ventilating system. The voltage regulator will be of an automatic type which vibrates intermittently.

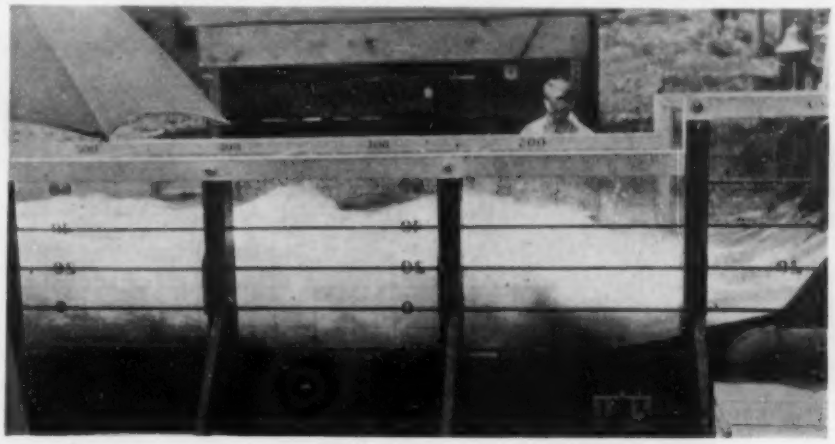
TABLE III. COMPARISON OF LARGE KAPLAN TURBINES

Station	Location	Diameter of Runner	Head in Feet	Cu Ft per Sec per Unit	Turbine Rating in Hp
Bonneville	U. S. A.	23′ 4″	50	12,200	60,000
Safe Harbor	U. S. A.	18′ 4″	55	8,000	42,500
Ryberg	Germany–Switzerland	23′ 0″	37.7	10,420	38,700
Svir	U. S. S. R.	24′ 4″	36.1	10,240	37,500
Dogern	Germany–Switzerland	23′ 0″	35.1	10,600	35,500
Vargon	Sweden	26′ 3″	14.1	11,090	15,200

Because of the physical location of the Bonneville power house, the surrounding topography, and uncertainty as to ultimate uses, the selection of electrical equipment is particularly difficult. Outdoor substations and switchyards have been studied for the Oregon shore and Bradford Island, but each location has serious disadvantages. To reach the Oregon shore it is necessary to pass under the deep navigation locks, and the situation at Bradford Island is complicated by the projected extension of the power house in that direction.

MODEL OF BONNEVILLE PROJECT COMPLETED

According to the plan now favored, each generator will be connected with its individual transformer bank through duplicate oil circuit-breakers to a main and an auxiliary 110-kv bus. Transformers are to be located on the headgate structures, and circuit-breakers and buses on the power house roof. Transmission lines at 110 kv will connect with buses through duplicate circuit-breakers. To reach the Oregon shore, transmission lines must cross the lock channel; to reach the Washington shore they must cross the main river channel. It is probable that future transmission lines will be located on both banks of the river.



A SPILLWAY MODEL FOR BONNEVILLE DAM BEING TESTED

CONSTRUCTION SCHEDULE AND CONTRACT QUANTITIES

As of July 6, 1934, contracts had been awarded for the power house foundation, the fishway excavation, and the concrete work on the intake structure and power house substructure. Earth-fill cofferdams had been constructed across the Bradford channel on the sand and gravel river bed, and 20 acres at the power house site had been unwatered by pumping. Pumping had amounted to 110 cu ft per sec under a head of 60 ft.

Excavation will be completed about October 1, 1934, and the substructure concrete by May 1, 1935, at which time the cofferdams will be removed to permit passing of the summer flood. The power house superstructure and two 250-ton cranes will be erected in time to install the turbines and generators in 1937.

Some of the principal quantities in the construction of the power house substructure are given in Table IV.

TABLE IV. CONSTRUCTION QUANTITIES FOR EXCAVATION AND SUBSTRUCTURE OF POWER HOUSE

Item	Estimated Quantities
Cofferdam fills	150,000 cu yd
Common excavation	300,000 cu yd
Rock excavation	325,000 cu yd
Class A concrete	125,000 cu yd
Class B concrete	15,000 cu yd
Reinforcing steel	20,000,000 lb
Structural steel	3,000,000 lb
Special steels and castings	500,000 lb

Class A concrete will be designed for a 30-day strength of 3,800 lb per sq in. and will be used throughout, except for 15,000 cu yd of Class B concrete, of 3,200-lb strength, in the north retaining wall, and about 10,000 cu yd of special water-tight concrete in the head wall and water passages of the power house. Water-tightness will be secured by increasing the proportions of fine

sand and cement in the mix and by vertical and horizontal copper water stops in all joints subject to water pressure. The maximum size of aggregate will be 3 in. except where reinforcing steel or the thinness of the walls limits the maximum size to $1^1/_2$ in.

The Bonneville Project is being constructed by the Corps of Engineers, U. S. Army. Colonel T. M. Robins is Division Engineer, Major C. F. Williams, District Engineer, and C. I. Grimm, M. Am. Soc. C.E., Chief Civilian Engineer in charge of the project, with headquarters in Portland, Ore. The project is under the general direction of E. M. Markham, M. Am. Soc. C.E., Chief of Engineers, Major General, Corps of Engineers, U. S. Army, whose headquarters are Washington, D.C.

Columbia Basin and Grand Coulee Projects

By F. A. BANKS

ASSOCIATE MEMBER AMERICAN SOCIETY OF CIVIL ENGINEERS
CONSTRUCTION ENGINEER, U. S. BUREAU OF RECLAMATION, ALMIRA, WASH.

MILLIONS of years ago, after the Columbia River had laboriously cut its way through 1,500 ft of solid basalt and granite, a glacier advancing southward from Canada crossed the canyon of the Columbia east of the Okanogan River and became the original Grand Coulee Dam. It raised the water surface of the river 1,500 ft and caused it to cut a new channel, now designated as the Grand Coulee—50 miles long, up to 900 ft deep, and 5 miles wide—and constituted the first step in the construction of the Columbia Basin Project. Receding later, the glacier permitted the river to return to its former channel and left the Grand Coulee a monument to its efforts.

During the process of erosion, a cataract was formed in the lower part of the coulee, the crest of which is 400 ft high and 6 miles long, now known as Dry Falls. The Grand Coulee, with its Dry Falls, is a magnificent example of erosion and is classed as one of the geological wonders of the world. Since the construction of improved highways, it has become the mecca of international geologists and other scientists.

RELATION TO COLUMBIA BASIN PROJECT

Present plans for the construction of the Columbia Basin Project involve the utilization of that part of the Grand Coulee above the Dry Falls for the storage of Columbia River water. This would be conveyed to the lands of the project by building dikes at each end of the Upper Coulee and by lifting the water up to the reservoir thus formed by means of the Grand Coulee High Dam, power plant, and pumping plant. The Grand Coulee Low Dam, which constitutes about a third of the work involved in the High Dam, is now being constructed exclusively for power purposes as a part of the national program for industrial recovery.

The irrigable lands of the Columbia Basin Project, which have been frequently referred to as the finest body of arid land awaiting reclamation in the West, lie in the southeastern part of the state of Washington, east of the Columbia River, south of Quincy, Ephrata, and Soap Lake, and north of the Snake River (Fig. 1). The project was originally conceived as a gravity project of from 1,000,000 to 1,750,000 acres, deriving its water supply by diversion from the Clark Fork of the Columbia River at Albany Falls, just above Newport, Wash., supplemented by storage in the Pend d'Oreille and Flathead lakes, located in Idaho and Montana, respectively. After thirty years of study by various local, state, and Federal organizations, the gravity plan has been supplanted by the present pumping plan, largely because of considerations of cost and possible interstate complications.

Present plans for the pumping project involve the irrigation of about 1,200,000 acres of land and include the following major features, here listed in the order in which they will probably be constructed: (1) the Grand Coulee High Dam and power plant; (2) the Grand Coulee pumping plant and pipe line; (3) the Grand Coulee north and south dikes, forming the Grand Coulee Reservoir; and (4) the main canals and distribution system.

DESIGN OF THE HIGH DAM

The site chosen for the Grand Coulee High Dam and power plant is on the Columbia River just below the head of the Grand Coulee, at which point the river is flowing north. The dam will be of the straight gravity type, 4,000 ft long, 500 ft high above the lowest foundation, and will contain more than 10,500,000 cu yd of concrete. Its purpose is to raise the water surface of the river 350 ft above low water, regulate the flow of the river, and provide a pressure head for the generation of power. Its spillway, controlled by drum gates, will

GRAND COULEE DAM SITE, LOOKING DOWNSTREAM

have a length of 1,800 ft and a capacity of 1,000,000 cu ft per sec. In addition, there will be in the east end of the spillway section at least 20 sluice gates, 5 ft 8 in. by 10 ft in size, for use in handling water during construction and drawing down the forebay for repairs after completion. Since 1913 the discharge of the Columbia River at this point has varied from 17,000 to 492,000 cu ft per sec, and the annual run-off has varied from 56,830,000 acre-ft in 1929 to 98,800,000 acre-ft in 1927, the mean being 79,000,000 acre-ft for the calendar year, corresponding to an average discharge of 109,000 cu ft per sec.

Extending upstream 151 miles to the Canadian boundary, the reservoir created by this dam will have a capacity of 5,000,000 acre-ft in the top 80 ft of its depth. It is of prime importance in the development of the river as a whole, since the regulation effected by it will increase the firm power output at all sites between the Grand Coulee and the mouth of the Snake River by 100 per cent, and at all sites below that point by 50 per cent. It is for this reason that the Grand Coulee High Dam holds the key position in the development of this great natural resource and should properly be the first to be undertaken.

The power plant will have an installed capacity of 1,890,000 kw and will consist of 18 units of 105,000-kw capacity, 9 on each side of the river. In addition, on the west side there will be two service units, of 6,000-kw capacity each, and a repair shop. The purpose of the power plant is to furnish power for the operation of the various pumping plants and for commercial purposes. It is estimated that 2,400 million kwhr will be required annually for irrigation pumping, and that 7,500 million kwhr of firm energy will be available for sale.

Pumping to Reservoir in Grand Coulee

Just upstream of the west abutment of the dam (left bank) will be the pumping plant with its capacity of 16,000 cu ft per sec. It will contain 20 units, each consisting of a single-stage pump having a capacity of 800 cu ft per sec when operating under a total head of 370 ft. Each pump will be direct connected to a 33,000-hp motor. The operating head of these pumps will vary from 280 to 360 ft, exclusive of friction.

Grand Coulee Dam Site, Looking Upstream

The Grand Coulee Reservoir, formed by the north and south dikes at each end of the upper Grand Coulee, will have a length of 23 miles, an area of 2,100 acres, and a capacity of 1,050,000 acre-ft. Its function will be to convey irrigation water through the coulee, regulate the supply to meet the demand, and permit the use of off-peak and secondary power for pumping purposes. The north and south dikes will be respectively 92 and 97 ft in height above the original ground and will present no unusual features.

Construction Progress at Grand Coulee Dam Site in August 1934

The Main Canal will extend southward from the south dike about 10 miles and then divide into the Main West Canal and the Main East Canal. These canals will serve 1,000,000 acres directly and 200,000 acres indirectly by repumping to a height not to exceed 100 ft.

It is estimated that the total cost of the dam and power plant will be $168,366,000, and that of the irrigation features, $208,265,000, a total of $376,631,000, exclusive of interest during construction. The maximum amount of investment up to the time when power revenues are estimated to be sufficient to take care of current expenditures and begin to reduce the investment is $260,000,000.

Construction of Low Dam Under Way

In the construction of the Grand Coulee Low Dam and power plant, which has been under way since the first of this year, about a third of the work involved in the High Dam is required. This dam will be of the straight gravity type, 3,500 ft long and 300 ft high above the lowest foundation, will contain more than 3,500,000 cu yd of concrete, and will involve 15,000,000 cu yd of excavation, as well as many other items in proportion. The spillway, which is uncontrolled, is 1,800 ft long and 150 ft above low water. With an overflow depth of 26 ft, leaving a freeboard of 5 ft, it will discharge a flood of 1,000,000 cu ft per sec. To dissipate the energy of the falling water, the downstream toe of the spillway will be formed into a bucket, the shape of which is the subject of experiments now being conducted on large-scale models in the hydraulic laboratories at Fort Collins and Montrose, Colo. Into the east end of

the spillway 20 sluice gates, 5 ft 8 in. by 10 ft, will be built.

All subaqueous excavation required for the High Dam will be done at this time, and its downstream toe will be constructed to serve as a permanent cofferdam during the work on the rest of the structure. Thus the unwatering expense and the incidental hazard during enlargement operations will be materially reduced. Arrangements have also been made to take over the contractor's camp and immobile plant and equipment in case the construction of the High Dam is authorized before the Low Dam is finished.

A section of the west side power house of the High Dam is to be constructed to house three main units, two service units, and the repair shop. A decision as to the exact type of unit to be installed is being deferred until more is known of the prospects for proceeding with the construction of the High Dam. Consideration is being given at this time to the installation of High Dam units with a capacity of 105,000 kw each, but with runners adapted to the head at the Low Dam, which will produce 34,300 kw each.

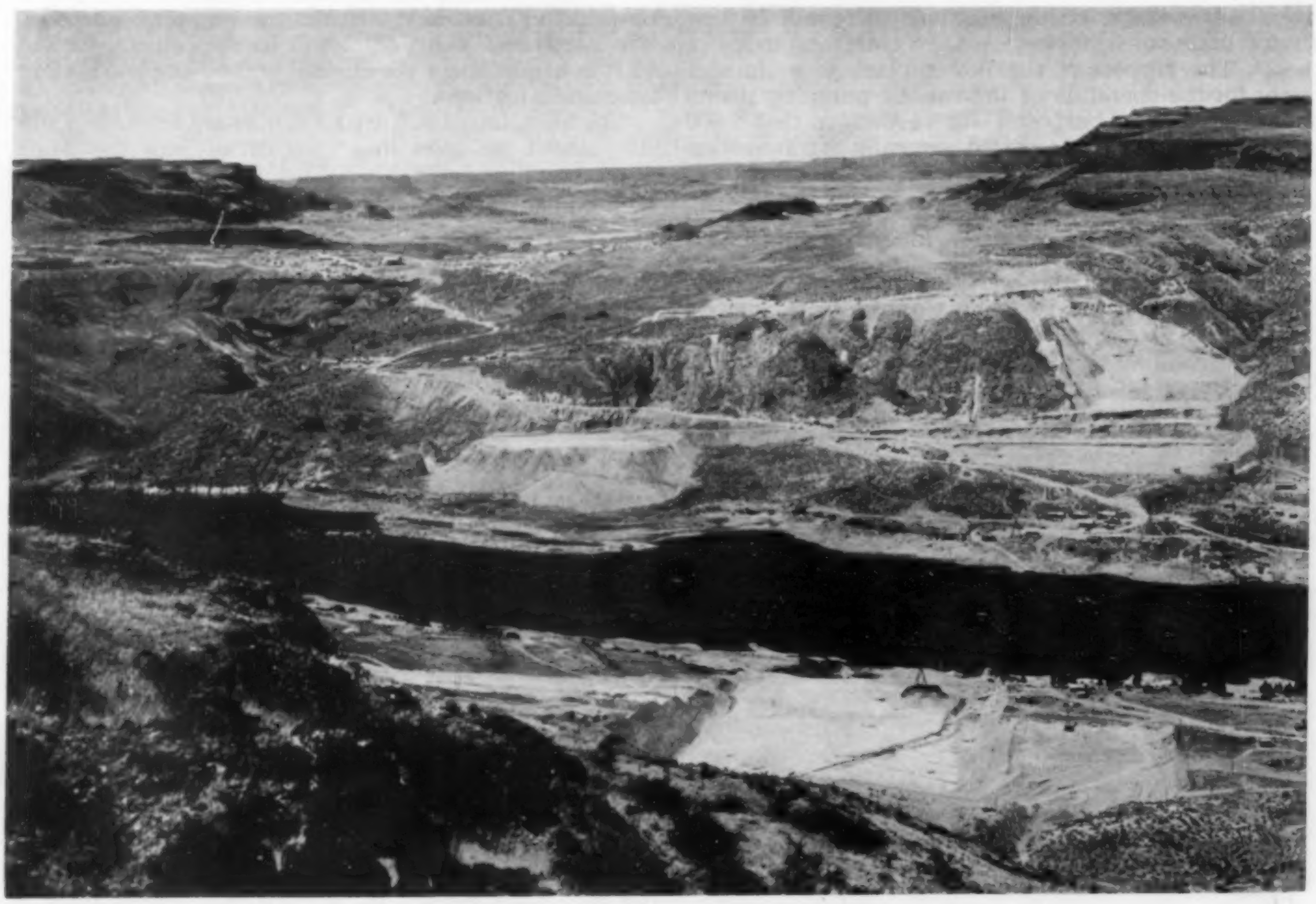
SATISFACTORY FOUNDATION CONDITIONS REVEALED

A very thorough exploration of the foundation for the dam has been made by means of 6 test pits and 115 diamond drill holes, both vertical and inclined, which have penetrated to a depth of 700 ft below low water. Granite bedrock of excellent quality, fulfilling every requirement for the foundation, is found at an average depth of about 70 ft below low water, the maximum depth so far disclosed being about 160 ft below low water in a pothole on the east side of the river. The bedrock is overlain with sandy clay, with occasional boulders, and with gravel strata.

As might be expected in a stream of this magnitude, having an annual fluctuation in height of water surface of 50 ft in ordinary years, the care and diversion of the river during construction presents a major problem, probably the most difficult one to be met. The clay in the bed of the river, while affording a means of securing a tight connection with the bedrock, when saturated in all probability will not have sufficient stability to support as high a cofferdam as will be required. Consequently it will be necessary to construct very substantial cellular cofferdams of steel sheet piles driven to bedrock. A number of different arrangements of the cofferdams have been considered. The one now in favor seems to be two U-shaped cofferdams, one running out from each shore to within 500 ft of the other. Within these the two ends of the dam would be constructed, leaving alternate panels in the spillway section at an elevation about 15 ft below low water and carrying the other panels well above low water. The 500-ft gap in the center would then be closed above and below by cofferdams, and the water would be turned through the low panels and ten of the sluice gates. After the center section was raised above low water, the low panels left on each side would be bulkheaded during low water and carried up as rapidly as possible.

LOCATION OF SUITABLE AGGREGATES IMPORTANT

Where so much concrete must be produced, the location of suitable aggregates is of prime importance. Fortunately, an extensive gravel pit of excellent quality, the surface of which lies 800 ft above the top of the Low



GRAND COULEE DAM SITE, COLUMBIA RIVER, WASHINGTON; GRAND COULEE IN DISTANCE

Dam, has been found on the east side (right bank) of the river about $1^1/_2$ miles below, that is, north of the dam site. The material is largely hard basalt of high specific gravity with some granite in the sand. There is a considerable excess of sand, which by wasting undesirable sizes, can be graded to the proper fineness modulus, that is, 2.50 to 3.00. The location of the gravel pit automatically fixes the location of the sand and gravel plant and the mixing plant on the east side of the river, where favorable topography has already fixed the location for the contractor's camp. This camp, constructed to house about 3,000 employees, will be modern in all respects and fully equipped with schools, commercial establishments, and other necessary facilities.

A permanent camp for the engineering staff, to be subsequently occupied by the operating force, has been located on the west side of the river about a half mile below the dam. It will contain an administration building, a small commercial section, a school, a garage, a warehouse, two dormitories, about 70 dwellings, and all the modern facilities.

ROAD, RAILROAD, AND BRIDGE CONNECTIONS

To provide ready access to both sides of the river, a cantilever highway bridge 950 ft long, with a 20-ft roadway and two 4-ft sidewalks, is being constructed across the river about 3,000 ft below the dam site. The present road to the ferry at the dam site will be destroyed by the construction of the dam, and a new road crossing the axis of the dam at the elevation of the roadway on the High Dam is being built from the head of the Grand Coulee to the new highway bridge.

To facilitate the transportation of 14,000 cars of cement and proportionate amounts of other materials, a standard-gage railroad 34.5 miles long is being constructed from Odair, near Coulee City on the Northern Pacific Railroad, through the Grand Coulee and down to the west shore of the river at the dam site. The maximum grade against the haul is 1 per cent; but in the direction of the haul, down the walls of the Columbia River Canyon, limited space requires considerable lengths of 5 per cent grade and about 1,000 ft of 6 per cent grade, as well as several switchbacks.

Power for construction purposes will probably be secured by a transmission line connecting with the Washington Water Power Company's distribution system at Coulee City, where energy at 110,000 v is available.

PROBABLE DATES OF COMPLETION

For the Low Dam the construction period has been fixed at $4^1/_2$ years, which places the completion date in the early part of 1939. The building of the High Dam would probably take 5 or 6 years after authorization, and the time required for the construction of the irrigation features would depend on the rate of possible settlement. At the rate of 20,000 acres per year, as has been estimated, it would take 60 years to complete the work. From these data it may be realized that a project of this magnitude calls for long-time planning and should be considered on the basis of average conditions.

In times such as these, a project of this character serves to start the wheels of industry, to provide employment for those who are idle in all parts of the country, and, as economic conditions become normal, to supply power at reasonable rates for new and expanding industries and homes.

DRY FALLS AND FALLS LAKE IN GRAND COULEE, WASHINGTON

Flow in Bends of Quarter-Turn Draft Tubes

Abstract of Paper Read Before Joint Session of Irrigation and Power Divisions at Vancouver Convention, July 12, 1934

By C. A. Mockmore

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The draft tube of a water turbine performs two principal functions: first, it permits placing the turbine runner above the tailwater; and second, it efficiently reduces the velocity of the water in its passage through the tube. The total draft head of the tube should not exceed 25 ft and should be such that the destructive action of cavitation will be avoided.

In general, draft tubes may be divided into two classes: those having straight center lines and those having curved center lines. It is quite generally conceded that the first class is better suited for all conditions of operation than the latter, particularly in cases where the water leaves the turbine with considerable components of whirling velocity. However, those having a straight, vertical center line may necessitate excessive excavation costs, so that an elbow type may be preferred. It is the elbow type of tube which was the subject of the study here discussed.

Theory of Flow in Bends

In the quarter-turn draft tube, the bend is the part that makes it distinctive. It is the part in which complications arise in the function of velocity reduction. These same complications are found in any channel where the water filaments are forced to undergo a general change of direction. If there were streamline flow of equal velocities at the entrance to a bend, and if friction could be eliminated, no complications would be encountered. With helical flow at the entrance to a bend, even without friction, complications will arise in the bend due to gyral action.

No pipe can be made in which friction does not exist; therefore the filaments of flow near the walls will have less velocity than those near the center. Thus as water enters a bend, spiral flow is automatically induced.

Apparatus Developed

Since the bend of the elbow draft tube marks the source of induced spiral flow, it was decided to experiment on bends of various designs. To be able to control the velocities of the entering filaments, the laboratory set-up shown in the illustration was devised.

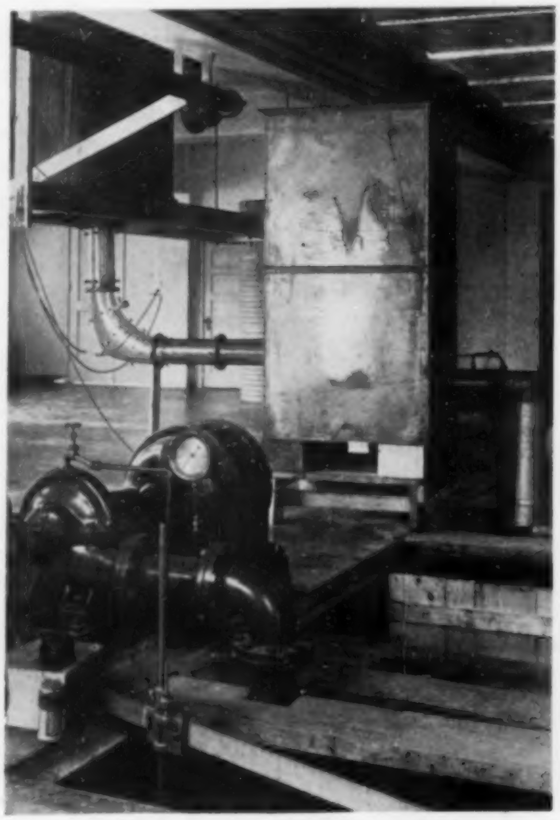
In order better to observe the conditions of flow in the experimental bends, they were made of transparent pyralin. A number of odd-shaped 90-deg bends were designed, built, and tested, among them several designed by the U. S. Engineers for the Bonneville Project on the Columbia River. The pyralin was purchased in sheets 21 by 50 by $^1/_8$ in. After some preliminary tests, it was found that this material would become very flexible at temperatures of about 275 F without having its transparency impaired. Thus it would be an easy matter to press the sheets into various shapes by means of moulds. The final assembling of the parts of the bend was done by using pyralin dissolved in acetone as a glue. The velocities of the water filaments were measured with a pitot tube. The water flowing from the test entered a concrete tank in which the elevations of the water surface were read from point gages; thus the rate of flow was established by volume.

Of the several odd-shaped 90-deg bends tested for direct flow, that designed in accordance with a suggestion made by the late Floyd A. Nagler, M. Am. Soc. C.E., caused the least hydraulic loss. In this bend the sections take an elliptical form, gradually flattened from a circle of 6-in. diameter toward the center of the elbow and resuming the circular form at the outlet. In it each cross section has an equal area. The elliptical cross section at the vertex of the bend has a major axis of 10 in. and a minor axis of 3.6 in. The radius on the center line of the bend is 15 in. Not only are the hydraulic losses due to induced spirals and eddying small, but the flattened shape has the advantage of avoiding excessive excavation in an actual draft tube installation.

The double spiral induced by the combined action of centrifugal force and friction on the pipe walls will cause more water to flow through one part of the lower leg of a tube divided by a bearing wall unless the partition is extended well around the bend into the upper leg. A twisted fin in the upper leg of a model for the purpose of correcting the whirl component of velocity tended to reduce the hydraulic losses through the tube.

Experience with pyralin, or celluloid, for making the models proved highly satisfactory and practical in these tests. Its use affords an easy and accurate means of manipulating a pitot tube as well as making photographic records of the flow.

This abstract is a digest of work done at the University of Iowa as a thesis for a Ph.D.



Laboratory Set-Up for Testing Bends

An Inter-Continental Highway System

Active Interest Shown in Planning a Road to Extend from Alaska to the Argentine

SINCE first officially expressed in 1923 at an international conference at Santiago, Chile, the idea of a Pan-American highway has been rapidly taking concrete form. In 1929 the First Inter-American Highway Congress was held and Congress appropriated funds for a major share of the cost of a reconnoitering survey for a route from the Rio Grande to Panama. The survey has now been completed, and the report to Congress has been ordered printed. Because of his intimate association with the survey as a representative of the United States, Mr. James is especially qualified to present the basic considerations and the conclusions of the report.

Existing highways in the United States provide a continuation of the route from the international border of Mexico to Canada. Ability to reach Alaska by land through British Columbia and the Yukon Territory has many advantages, but the route traverses a sparsely settled and forbidding terrain. Nevertheless, studies made by Canadian and American engineers indicate that the route is not only entirely feasible but wholly desirable. To provide a 16-ft graveled roadway over the unconstructed 1,200-mile section is estimated to cost nearly $14,000,000. Major Elliott was a member of the special commission appointed by the President to study the Alaska connection with the cooperation of Canadian representatives.

The following two articles have been abstracted from the papers presented before the joint session of the Highway and Construction Divisions held on July 12, 1934, at the Vancouver Convention of the Society. The dream of motoring from the Arctic Circle in Alaska to the South American continent over an improved highway is shown to be practical from an engineering and construction standpoint. If the vital matter of financing can be arranged it bids fair to become a reality.

From Panama to the Rio Grande by Highway

By E. W. James

Member American Society of Civil Engineers

Chief, Division of Highway Transport, U. S. Bureau of Public Roads, Department of Agriculture, Washington, D.C.

REFERENCE to the Inter-American Highway has been made in various terms ranging from "silly dream" to "magnificent conception." Briefly, it is a highway to connect the two Americas. Such a road, to extend from the Rio Grande to Panama, must cross Mexico and the six Central American Republics. On the western frontier of Panama it reaches Colombia, the first country in South America proper. It forms a substantial part, and from the point of view of the United States, the most important part of the still greater Pan-American Highway which would eventually come into being to connect all the countries of the western hemisphere.

PART OF A PAN-AMERICAN HIGHWAY

The idea of a Pan-American route was first expressed officially in 1923 at the Fifth International Conference of American States at Santiago, Chile. The idea developed rapidly, until in 1929, following the second Pan-American Congress of Highways at Rio de Janeiro, Brazil, a meeting was held at Panama in October, which has become known as the First Inter-American Highway Congress. The delegates there assembled attempted to reduce what seemed a dream to terms which might, under wise management, be expressed in the materials of modern highway construction. From the beginning the United States has been active in developing the idea. The First Inter-American Highway Congress at Panama was held because the time had come for definite action by the United States and by the several countries between the Rio Grande and South America. The Congress of the United States, after recommendations by both President Coolidge and President Hoover, had appropriated a sum sufficient to reconnoiter a route for a road from Panama to the Rio Grande.

As the administration of the act obviously required the acquiescence and cooperation of the several Spanish-speaking countries concerned, a meeting of delegates of their governments was called at Panama, at which all but Mexico were represented. These delegates recorded what in their minds an Inter-American Highway should do, in terms that were practical and concise. The route, if feasible, should be extended to the capitals of

Modern Road Construction in Panama
Illustrating the Ultimate Standard of Width, Alignment, and Grade for the Inter-American Highway

each of the countries of Mexico and Central America and as far as possible should utilize the existing roads of each country, especially the improved sections.

This survey, which was authorized and financed largely by the United States in cooperation with the sister republics, has now been completed, and a report has been prepared, submitted to Congress, and ordered printed. The document discloses that an entirely feasible route,

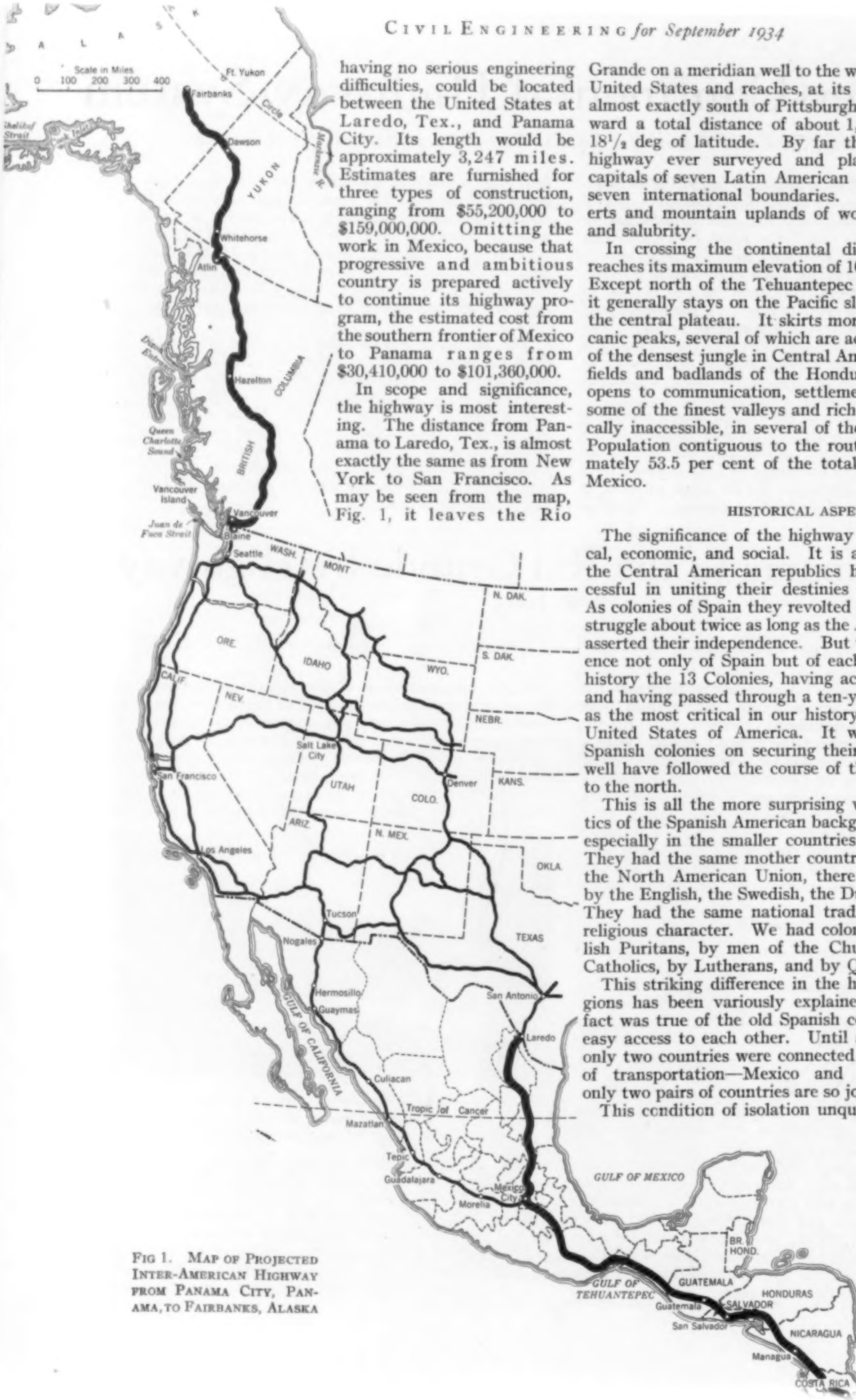


FIG 1. MAP OF PROJECTED INTER-AMERICAN HIGHWAY FROM PANAMA CITY, PANAMA, TO FAIRBANKS, ALASKA

having no serious engineering difficulties, could be located between the United States at Laredo, Tex., and Panama City. Its length would be approximately 3,247 miles. Estimates are furnished for three types of construction, ranging from \$55,200,000 to \$159,000,000. Omitting the work in Mexico, because that progressive and ambitious country is prepared actively to continue its highway program, the estimated cost from the southern frontier of Mexico to Panama ranges from \$30,410,000 to \$101,360,000.

In scope and significance, the highway is most interesting. The distance from Panama to Laredo, Tex., is almost exactly the same as from New York to San Francisco. As may be seen from the map, Fig. 1, it leaves the Rio Grande on a meridian well to the west of the center of the United States and reaches, at its Isthmian end, a point almost exactly south of Pittsburgh, Pa. It moves eastward a total distance of about 1,300 miles and covers $18^1/_2$ deg of latitude. By far the longest continuous highway ever surveyed and planned, it touches the capitals of seven Latin American republics, and crosses seven international boundaries. It traverses both deserts and mountain uplands of wonderfully fine climate and salubrity.

In crossing the continental divide seven times, it reaches its maximum elevation of 10,550 ft in Guatemala. Except north of the Tehuantepec Peninsula in Mexico, it generally stays on the Pacific slope when it is not on the central plateau. It skirts more than a score of volcanic peaks, several of which are active, penetrates some of the densest jungle in Central America, passes the lava fields and badlands of the Honduras coastal plain, and opens to communication, settlement, and development some of the finest valleys and richest areas, now practically inaccessible, in several of the countries traversed. Population contiguous to the route comprises approximately 53.5 per cent of the total population south of Mexico.

HISTORICAL ASPECTS

The significance of the highway is threefold—historical, economic, and social. It is a surprising fact that the Central American republics have never been successful in uniting their destinies in a common effort. As colonies of Spain they revolted and, after a period of struggle about twice as long as the American Revolution, asserted their independence. But this was an independence not only of Spain but of each other. In our own history the 13 Colonies, having achieved independence, and having passed through a ten-year period considered as the most critical in our history, united to form the United States of America. It would seem that the Spanish colonies on securing their independence might well have followed the course of the American colonies to the north.

This is all the more surprising when the characteristics of the Spanish American background are considered, especially in the smaller countries of Central America. They had the same mother country, Spain, whereas, in the North American Union, there were states founded by the English, the Swedish, the Dutch, and the French. They had the same national traditions, and the same religious character. We had colonies founded by English Puritans, by men of the Church of England, by Catholics, by Lutherans, and by Quakers.

This striking difference in the history of the two regions has been variously explained. One outstanding fact was true of the old Spanish colonies: they had no easy access to each other. Until about four years ago only two countries were connected by any passable line of transportation—Mexico and Guatemala. Today, only two pairs of countries are so joined.

This condition of isolation unquestionably played its part in the original separation of the Spanish-American colonies and has exerted a lasting and effective influence in creating and maintaining a separatist spirit in all of them. If the Inter-Ameri-

can Highway can be built, it will remove one of the historical causes of separation and pave the way for a possible union of effort, resources, and purpose and for prosperity.

ECONOMIC SIGNIFICANCE

The economic significance of the highway is more immediate than the historic. All the countries are agricultural and most of them depend on one or two crops for export production. Practically none is self-supporting in foodstuffs. A main highway, with its inevitable branches, will not only provide an avenue of exchange between them, but will serve to promote a much better distribution of internal produce. New areas at present inaccessible for all commercial production will be brought into contact with the more densely populated areas, and small landholders will be encouraged to produce a variety of crops for local markets and for export to closely adjacent countries. Land now lying waste will be opened up to settlement and development. Mining and timbering will be facilitated.

Socially, the effects of a highway through Central America have perhaps the greatest significance, although their evaluation is doubtless the most difficult. An involved set of relationships may be observed today between the world sugar market, the internal political condition of Cuba, and the financial relations of Cuba to her creditors. Countries which depend on one or two staple products must find a good market or languish.

FERRY BOAT "PRESIDENT ROOSEVELT" IN THE PANAMA CANAL
Connecting the Highway to Panama City

When they languish their foreign purchases decline and trade vanishes. The only way to interrupt this series of events is to diversify production.

Practically all the nations of Central America can be practically self-supporting except for manufactured goods; but today none is. The small landholder and merchant must be given a sense of security, political conditions must be stabilized, internal trade must be increased, and the interchange of foodstuffs back and forth across the numerous international boundaries must be facilitated. The Inter-American Highway will be an important factor in furthering these ends.

In summary it may be said that coincident with the opening of an Inter-American Highway connecting all the capitals of Central America will be the facilitation of internal trade and the exchange of locally produced commodities among these centers; the development of new products on a commercial scale, made possible by better communication; the settlement of new lands and the promotion of wider activities in agricultural, mineral, and lumber production; the inflow of tourists; and, most of all, the freedom of travel among all the countries for their own citizens, with the resulting broadening of outlook, exchange of ideas, and realization of like customs, ambitions, and purposes. These influences will tend to stabilize political conditions, promote social security, make the countries more nearly self-supporting, widen the list of exports, and make the entire region a better market for manufactured articles.

TYPICAL COSTA RICAN ROAD NEAR SAN JOSÉ
The Proposed Route Follows This Road for Thirty Miles

Such a conception of an Inter-American Highway has undoubtedly been the source of the support which the idea has had since it was first officially started in 1923 and which led finally to provisions for a reconnaissance survey in 1929.

Among the interesting features of this survey is the use of airplane photographs and the resulting mosaics to map the region contiguous to the line. The absence of adequate maps for most of the territory covered made such a method desirable. Very little actual reconnaissance was done by plane, the aerial photographs being used to supply a base for mapping only. With the reconnaissance were combined elaborate economic studies of the territory traversed, and a conscious effort was made to develop valuable areas, utilize existing construction, and make the single line of highway as potentially valuable as possible as a basis for future highway development in all the countries.

From a study of the map, Fig. 1, it will be noted that the line of the highway generally follows the Pacific watershed, thus avoiding the larger rivers, the larger swamp areas, the heavier precipitation, and the greater number of indirect connections between developed areas that would be required on a line along the Atlantic side of the divide.

GENERAL ALIGNMENT FROM PANAMA NORTH

After crossing the Panama Canal by the Thatcher Ferry at Balboa Basin, near the Pacific entrance, the proposed route continues westward along the coastal plain. The Republic of Panama has already surveyed and practically completed a main highway for over 300 miles to Concepcion, and the maximum elevation in this distance is not over 700 ft. At Concepcion the proposed route turns northward and follows a spur of El Volcan de Chiriqui, a beautiful peak some 11,300 ft high. The ridge is followed for 19 miles on a very well sustained and uniform gradient to the plateau at the base of the volcano at elevation 4,375 (El Hato). Here it turns westward in a generally descending course across the Rio Chiriqui Viejo before rising to 3,650 ft on the Santa Clara ridge between the Chiriqui Viejo and Brus rivers. The international boundary between Costa Rica and Panama follows this divide more or less closely. From

here the route descends along another narrow ridge known as the Sabana de Limon, which is largely open grass lands, with no adverse grades, to the point at the barrio of Paso Real, where the Rio Brus and the Rio General join to form the Rio Diquis.

From Paso Real, on the Rio General, the line follows the right bank of the stream for a distance of approximately 65 miles, rising from an elevation of 400 ft to that of 3,900 ft at the divide between the Rio Pacuar, the right branch of El General, and the Rio Sevegre.

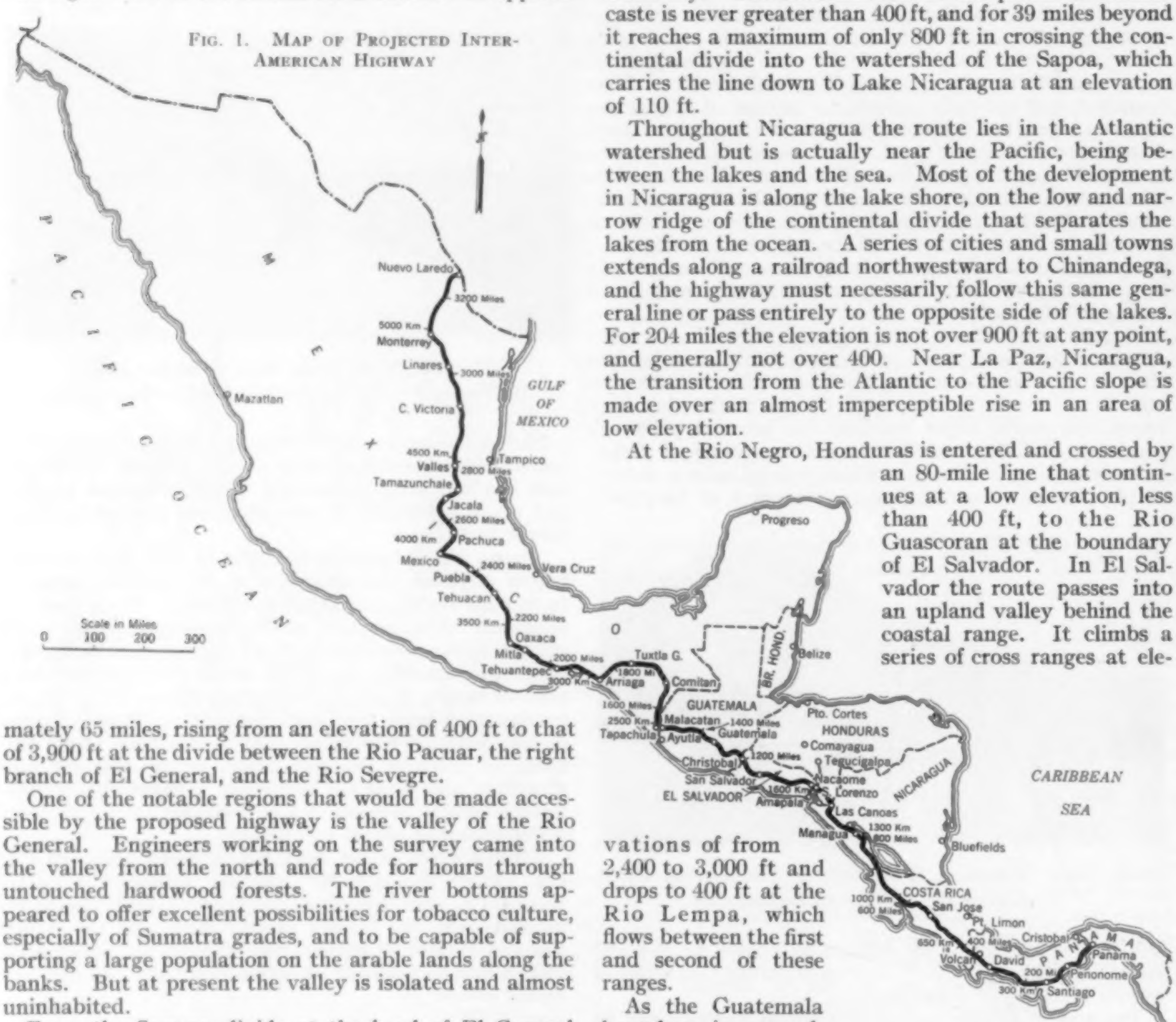


FIG. 1. MAP OF PROJECTED INTER-AMERICAN HIGHWAY

One of the notable regions that would be made accessible by the proposed highway is the valley of the Rio General. Engineers working on the survey came into the valley from the north and rode for hours through untouched hardwood forests. The river bottoms appeared to offer excellent possibilities for tobacco culture, especially of Sumatra grades, and to be capable of supporting a large population on the arable lands along the banks. But at present the valley is isolated and almost uninhabited.

From the Sevegre divide at the head of El General Valley the reconnoitered line enters a region of spurs from the main cordillera that extend practically to the shores of the Pacific. The line crosses the Sevegre and Naranjo rivers and after leaving the Honda River, a short branch of the Naranjo, proceeds to San Marcos up the Rio Parita, and beyond to a point called El Jardin, which is on the continental divide approximately at elevation 7,275 ft. Following along the crest of the divide in more or less open meadow lands for 25 miles, the proposed route reaches El Alto, at elevation 5,125 ft, and joins the main highway of the Meseta Central, which crosses the continental divide between San José and Cartago. This is a main highway of modern design, which crosses the Meseta through a line of picturesque old cities of Spanish colonial type, including of course the capital city of San José. At a point near the town of San Ramon the descent from the plateau begins and continues through Esparta (elevation 600 ft) a distance of 28 miles to the Rio Barranca (elevation 200 ft) in the Pacific coastal plain.

For 98 miles the route then skirts the foothills, crossing many small streams that rise in the central cordillera, which rapidly shrinks in height and width as it approaches the San Juan Valley along the Nicaragua boundary. The elevation across the plains of Guanacaste is never greater than 400 ft, and for 39 miles beyond it reaches a maximum of only 800 ft in crossing the continental divide into the watershed of the Sapoa, which carries the line down to Lake Nicaragua at an elevation of 110 ft.

Throughout Nicaragua the route lies in the Atlantic watershed but is actually near the Pacific, being between the lakes and the sea. Most of the development in Nicaragua is along the lake shore, on the low and narrow ridge of the continental divide that separates the lakes from the ocean. A series of cities and small towns extends along a railroad northwestward to Chinandega, and the highway must necessarily follow this same general line or pass entirely to the opposite side of the lakes. For 204 miles the elevation is not over 900 ft at any point, and generally not over 400. Near La Paz, Nicaragua, the transition from the Atlantic to the Pacific slope is made over an almost imperceptible rise in an area of low elevation.

At the Rio Negro, Honduras is entered and crossed by an 80-mile line that continues at a low elevation, less than 400 ft, to the Rio Guascoran at the boundary of El Salvador. In El Salvador the route passes into an upland valley behind the coastal range. It climbs a series of cross ranges at elevations of from 2,400 to 3,000 ft and drops to 400 ft at the Rio Lempa, which flows between the first and second of these ranges.

As the Guatemala boundary is crossed, the line leaves the interior valley and again enters the cordilleran upland, rising from the last depression in El Salvador at 1,700 ft to 6,200 ft at San Vicente, Guatemala, in a distance of 83 miles. Here the main divide is crossed and the line drops from the rim, so characteristic of cordillera uplands, to an elevation of 4,950 ft at Guatemala City. Behind the range, with its series of 18 or more named volcanoes, the route continues to rise again as it leaves the Guatemala Valley in a northwest direction to find a way out to the Pacific lowlands. But little adverse grade is experienced as the elevation increases to 7,025 ft near San Rafael, to 9,900 ft just beyond Tecpan, and finally to 10,550 ft at Las Flores, where the maximum elevation between the United States and Panama is reached. At Palo Gordo the elevation is 8,200 ft, whence a sustained grade of 38 miles brings it down to 1,000 ft at the Suchiate River, which marks the Mexican line.

Drainage conditions along so varied a route, in a region having a heavy annual precipitation confined to a rather definitely limited rainy season, must be expected to present some difficulties. Between the Canal and David, Panama, all the needed bridges are in place. But between David and the Mexican border at the Suchiate River, 189 bridges are listed as required, of which 52 are longer than 100 ft. The longest structure needed is a bridge 1,000 ft long across the Rio Lempa in El Salvador. The Guascoran River, between Honduras and El Salvador, calls for a 975-ft crossing, and the two principal streams in Honduras, the Choluteca and the

SPANISH BRIDGE IN GUATEMALA, BUILT BY SLAVE LABOR IN 1582
The Inter-American Highway Location Crosses the Esclavos River Here

Nacaome, require 600 and 660-ft structures, respectively.

In all, 20,070 ft of bridging will be needed in spans of 40 ft or more. The heavily dissected terrain found everywhere along the route, either on the line itself or adjacent to it, will require a very heavy installation of smaller structures, including culverts, totaling, it is estimated, in excess of 699,000 lin ft.

ROUTE IN MEXICO UNDER CONSTRUCTION

In Mexico the line adopted by the Comision Naçional de Caminos is followed. It will pass through Tapachula near the Suchiate River, turn eastward to the central range at Comitan, and proceed thence to Tuxtla-Gutierres. Returning from this city to the coastal plain, the line is projected through San Geronimo to the Tehuantepec River and up the course of that stream to high country around Mitla and Oaxaca. Thence the line has been partly opened to Tehuacan, from which point the Mexican Government is now completing a

ROAD FROM SAN SALVADOR TO LA LIBERTAD
El Salvador Is Well Improved with Roads

road to Puebla. A modern highway has already been completed from Puebla to Mexico City and northward to Colonia. During the present year the government expects to finish all sections of the route through Valles, Ciudad Victoria, Montemorelos, and Monterrey to Nuevo Laredo on the Rio Grande. This section from Colonia to Nuevo Laredo has already been graded, and all but two bridges are completed. Some additional rock excavation in the mountain section and some surfacing remain to be done.

CONGRESS AIDS WORK

The 73d Congress, which has just adjourned, appropriated funds for continuing the surveys in cooperation with the Central American countries and also provided funds for use in promoting construction on some advantageous plan still to be worked out.

This undertaking is a magnificent one, significant for the entire Western Hemisphere. The outstanding adventures in transportation in the Americas have been the completion of the Union Pacific Railroad, the opening of the Panama Canal, and the joining of the railway line through the southern Andes between the Argentine and Chile. On completion, the Inter-American Highway will take its place among these large undertakings, which are international and continental in their effects on the transportation of the western world.

The Alaska–United States Highway

By MALCOLM ELLIOTT
MEMBER AMERICAN SOCIETY OF CIVIL ENGINEERS
MAJOR, CORPS OF ENGINEERS, U. S. ARMY, WASHINGTON, D.C.; FORMERLY PRESIDENT OF THE ALASKA ROAD COMMISSION

NOW well developed from coast to coast and from Canada to Mexico, the highway system of North America lacks only extensions through Central America to Panama and northwestward through Canada to Alaska to become a truly comprehensive and cohesive system continental in scope. The southerly extension to the Isthmus of Panama has received much consideration and is progressing toward its goal. A possible northern extension of the system (Fig. 1) to connect the United States with Alaska by a road through British Columbia and the Yukon Territory will be here discussed. The isolated road systems in the northern territories have not now any highway connection with the great body of the continent to the south. Therefore Alaska and the Yukon, though physically a part of the continent, are from the viewpoint of transportation an island, accessible only by boat or airplane.

From the data at hand it appears that the most suitable route from various viewpoints is about 2,204 miles long, measured from Vancouver. The completed part aggregates about 1,021 miles, leaving 1,183 miles to be built. The division of this mileage between provinces is shown in Table I.

On a project of this kind, extending through long

stretches of sparsely settled country, construction problems vary greatly from those encountered in ordinary road-building practice. Instead of being built to standards and specifications that will ensure from the start a surface of relatively high and uniform quality, the pioneer road is constructed to merely satisfy the immediate demands of traffic at the least possible expense. Priority is generally given to work required to overcome the most serious obstacles—to make passable those places that are impassable. Stretches of country where vehicles can move overland may be ignored entirely in the first stages of the project. Thus in a typical case a route may be laid out initially as a mere pack trail. As the volume of traffic increases, wagons will come into use, and after improvement of the road to wagon standards, the demands of automobile traffic will force further improvement.

TABLE I. STATUS OF ALASKA-UNITED STATES HIGHWAY IN ROUTE MILES

LOCATION	COMPLETED	NEEDED	TOTAL
British Columbia	880	520	1,400
Yukon Territory	50	480	530
Alaska	91	183	274
Total	1,021	1,183	2,204

Construction work is likely to be scattered over long distances and undertaken at localities but poorly served, if at all, by existing roads. This makes the securing of materials a difficult problem and entails the use of local materials to the utmost. For this reason the location of a section of the road is often changed to pass near suitable deposits of gravel for surfacing and growths of timber for bridges and culverts, even though the length may be greater than a route selected on the basis of distance and grade alone.

In pioneer localities detours are generally impracticable and traffic must be allowed to use the road while under construction if the lives and business interests of the people depending on it are not to be seriously interfered with. The maintenance of traffic during construction not only influences methods of work but also may require the active assistance of the road-building crews in keeping vehicles moving.

Financing of main roads in sparsely settled regions is generally the responsibility of the larger governmental units such as provinces, states, territories, or the national government. Short sections of through routes and local branches may be built by local effort either from taxes or by direct labor furnished by the settlers, but the connection of the local road systems into a coordinated route is generally beyond the capacity of local interests. In the United States this principle is recognized by the extension of Federal aid according to a formula, taking into consideration the area of the state and the area of the public lands contained in it. The result is that in thinly settled states with a large public domain Federal contributions for the construction of main routes may reach over 80 per cent of the total cost. In the outlying territories Federal participation is necessary to an even greater extent.

All of these factors will be found to apply in some degree to the proposed highway to Alaska. The first through connection will probably be of low type, the chief attention being given to making passable those sections that are now impassable. Local materials will be used for surfacing and bridges; use of the road will be coincident with its construction; and the cost will be defrayed in large part by the provincial, territorial, and national governments. The development of the country

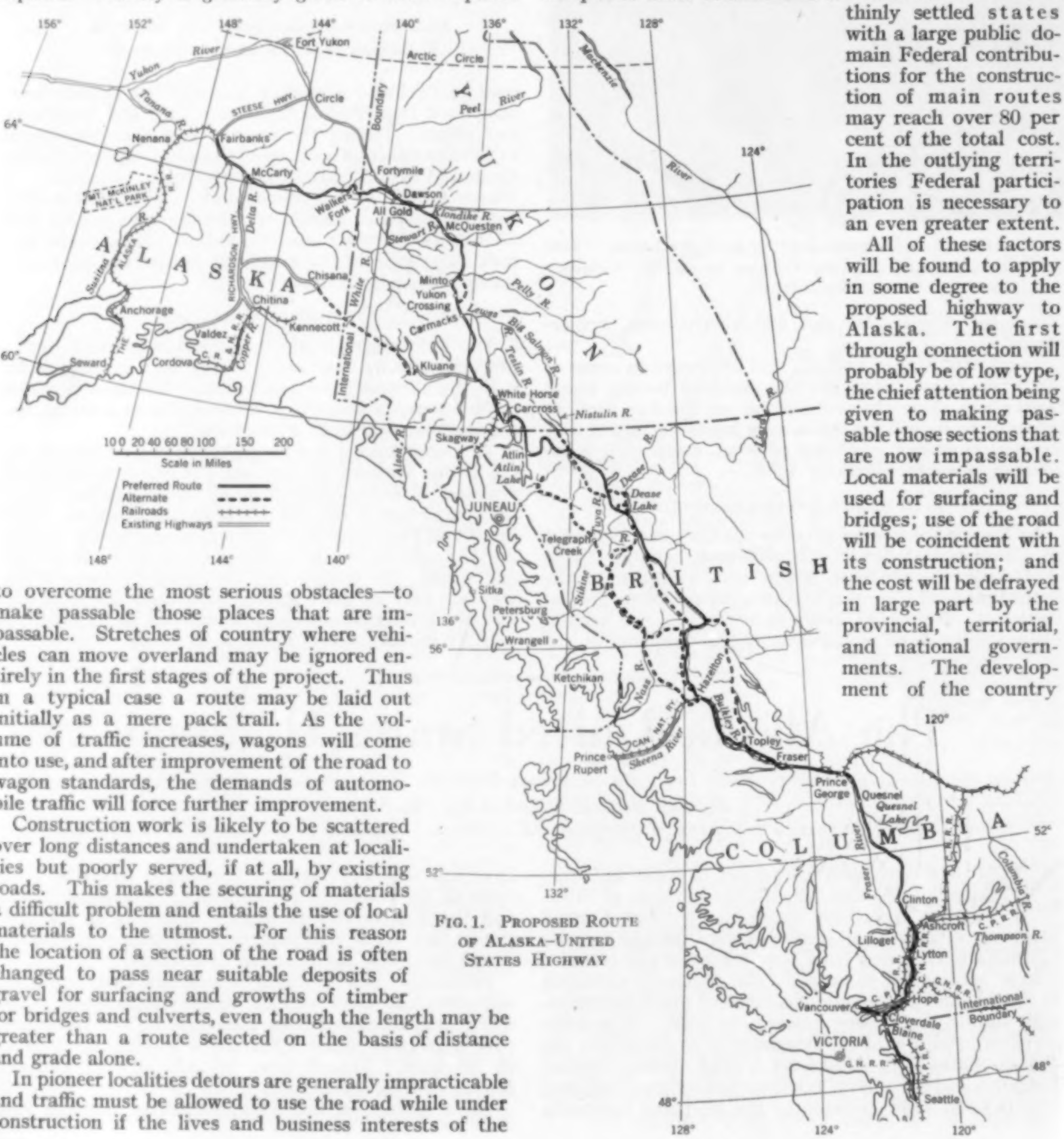


FIG. 1. PROPOSED ROUTE OF ALASKA-UNITED STATES HIGHWAY

for September 1934 VOL. 4, NO. 9

along the route—now a wilderness in part—should keep pace with the construction program. Scarcely will it be made passable for wagons before automobiles will attempt to use it. When they become mired there will be persistent agitation for a more reliable surface, until finally not only by national and territorial, but by strictly local effort, a standard in keeping with reasonable traffic demands will be attained.

TOPOGRAPHIC AND CLIMATIC CONDITIONS

In general the topographic and climatic conditions to be encountered on the road to Alaska are not greatly different from those in the northern part of the United

Current-Operated Ferry Across the Tanana River, Alaska
On the Richardson Highway, 2,113 Miles from Vancouver

States and the interior of Canada. There are wooded and open areas, rolling country, mountains, and valleys. So far as we know, the highest elevation will be about 4,500 ft above sea level. The summers are temperate and pleasant and without abnormal rainfall, but the winters are consistently cold, with deep snows in the mountains and moderate ones in the wider valleys. Winter travel over the existing roads is not generally blocked except in passes and other places where the drifts are abnormally deep. Either automobile or tractor traffic can be maintained readily throughout the year over a large part of this route when completed.

Especially in the Yukon Territory and Alaska, the subsoil is permanently frozen and in many sections this condition extends down to bedrock. Only the surface thaws in summer. The upper layer of moss and other vegetation blankets the frozen soil beneath, which varies in character from frozen earth to clear ice. When the surface is removed by grading, the subsoil melts to a semi-liquid, which may require an entire season to dry out and consolidate. In many cases it is the practice to strip off the surface soil one year and do the grading the next. By the constant thawing of the surface, a generally wet soil condition is produced, which constitutes a great impediment to road building if it is not handled in the manner which experience has developed. Even on hillsides that from a distance appear to be bare and dry there may be swamps caused by small pools retained by moss and grass roots, which have slumped downward under the action of the surface drainage so as to form small dams. On level ground, where drainage is difficult, recourse must often be had to corduroy until adequate drainage can be attained.

In the summer poor natural drainage interferes greatly with overland transportation of equipment and supplies in advance of and during construction. For this reason great reliance is placed on winter transport by means of tractors and sleds. Their operation in subzero weather presents no insuperable obstacle to those accustomed to it. Some items of food, and gasoline, oil, lumber, and many other supplies not subject to damage by exposure to intense cold can be freighted over the ice and snow and cached at convenient points for the next season's work. Cutting and hauling of timber for bridges and culverts

Maintenance Camp at Summit Lake on the Richardson Highway, Alaska
Here the Road Crosses the Divide Between the Pacific Ocean and Bering Sea

and rock excavation can also be done conveniently and efficiently in winter. This work not only accelerates construction but also partly stabilizes employment by leveling off the summer peaks and winter depressions.

Perhaps the easiest way to visualize the project is to start at the southern end and follow the trail through British Columbia and the Yukon Territory to Alaska, by the aid of the map, Fig. 1. With Vancouver, B.C., as the starting point, the three main sections of the project will be considered in order. The project is so divided not only because of the three territorial jurisdictions through which it passes, but also because of physical characteristics.

SECTION ON BRITISH COLUMBIA

First there is the section in British Columbia, which has a length of 1,400 miles, of which about 880 miles have been completed and are now in use. The completed section extends from Vancouver to Hazleton, first going up the Valley of the Fraser River to its headwaters and then descending the Bulkley River to its junction with the Skeena, a northern stream which discharges into the Pacific Ocean in the vicinity of Prince Rupert. The lower Fraser Valley is a highly developed section in which the industries are farming, dairying, lumbering, and mining. Every few miles there are cities and towns connected by railroads, electric lines, and fine highways. The roads have been developed progressively from the early trails and wagon roads built by the Royal Engineers and the settlers to supplement steamboat navigation on the Fraser River. During the fifties and sixties of the last century, this waterway was the main reliance of the settlers in conducting their intensive gold mining and other activities.

After passing through the canyons of the lower Fraser River, the road emerges into a vast rolling plateau of open country mostly devoted to grazing. This is the section known as the "Cariboo," a name derived from the vast herds of these animals which roamed there before the settlers came. The road connects with the Canadian National Railway at Prince George.

From Vancouver to Prince George, for 525 miles, the Cariboo Road has a high-type gravel surface and is well located and well graded. It adequately serves the country through which it passes and provides also a scenic route of high rank. From Prince George the general trend is northwestward, paralleling the railroad.

It goes up the Nechako River, a tributary of the Fraser and crosses a picturesque plateau and a chain of lakes forming part of the headwaters of the Fraser River system. This region is less thickly populated than the territory south of Prince George and the road is not as good as that through the southern, more heavily traveled section. At the head of the Nechako River, at an ele-

HIGHWAY IN THE FRASER RIVER CANYON, BRITISH COLUMBIA, 125 MILES FROM VANCOUVER

vation of about 2,300 ft, the highway crosses the divide and follows down the Bulkley River to Hazleton, 830 miles from Vancouver. From this point a low-type road has been pushed about 20 miles to the north, where it tapers out to a mere trail. This constitutes the only overland route to the northern part of British Columbia.

The part of British Columbia north of Hazleton is entirely different from that to the south. The little traveled, thinly inhabited, and almost unprospected region between Hazleton and Atlin has been reconnoitered within the past few years by aerial and ground parties sent out by the government of British Columbia to find a suitable general location for the road to the north. A wealth of valuable information has been gathered and is now on file with the provincial Department of Public Works, showing that there are several practicable routes. The favored one goes up the Skeena River and then crosses the headwaters of the Stikine River to Dease Lake and Lake Atlin, where an upper branch of the Yukon has its source. The highest summit is not expected to be more than 4,500 ft above sea level. The existing trail along the telegraph line is west of this location. It is more mountainous and considered less promising from a road-building standpoint. When the time comes to give the project more intensive study, the sketches and notes made by these explorer-engineers, as well as their aerial photographs, will furnish invaluable data as to the conditions that must be met and overcome in this section.

In Northern British Columbia is the lake area forming the divide from which the drainage flows in three directions: northward through the Mackenzie system to the Arctic Ocean, northwestward through the Yukon system to Bering Sea, and southwestward to the Pacific Ocean. The Yukon Valley, crossing the southeastern corner of the Yukon Territory, gives access to Alaska.

THE ROUTE THROUGH THE YUKON TERRITORY

At the northern boundary of British Columbia, 1,370 miles from Vancouver, is Lake Atlin, which is connected with the Skagway-Whitehorse trail by a chain of lakes separated by low portages. This trail leads from the Pacific Coast watershed over White Pass to the interior of the Yukon Territory. It was the "trail of '98," over which cargo was transported on men's backs, on pack horses, and in wagons. It now carries a narrow-gage railroad, which is joined by the route from Atlin near Carcross. From this latter point an existing low-type road parallels the railroad for 43 miles to Whitehorse, 1,510 miles from Vancouver.

The general route of the proposed highway is much better known through the Yukon Territory than through the northern part of British Columbia. This is because in the Yukon it parallels the now traveled river route northward and down the Yukon River, which is navigable for typical river steamboats. This great stream extends through the Yukon Territory and Alaska all the way from Whitehorse to Bering Sea, about 2,300 miles. Navigation is usually closed by ice from November until late in May, during which time a regular stage service for passengers and freight is maintained over the frozen river and across country between Whitehorse and Dawson. The horses formerly used on this route have been supplanted by tractors.

There is also occasional overland travel in summer over parts of the route between Whitehorse and Dawson which are passable in fair weather for light cars. The passable sections are from Whitehorse to Yukon Crossing, 153 miles, and from Allgold down the Klondike River to Dawson, about 34 miles. The section between Yukon Crossing and Allgold can be classed only as a trail. Undoubtedly the through route would incorporate, at least at first, parts of the existing low-type road, which could be improved to a suitable standard. Some of this

QUESNEL ON THE CARIBOO TRAIL, 446 MILES FROM VANCOUVER

mileage is of such low type that it has been excluded from the general statement of completed road given in Table I.

The principal obstacles are the Yukon and Stewart rivers, which would require crossings from 800 to 1,000 ft long, but ferries can be used until bridges can be provided. At Five Finger Rapids, about 12 miles above the present crossing, where the river is partially obstructed by a number of projecting rocks that would serve acceptably as bridge piers, there is a favorable location for a bridge over the Yukon. The relocation of the road to connect with such a crossing presents no difficulties.

Dawson, 1,865 miles from Vancouver, is the center of the Klondike gold fields, famous in the nineties for the richness of their yield of placer gold. The Klondike is still a producing camp, but except in the minds of the old inhabitants the romance and glamour are gone.

Gold is taken out methodically and efficiently by modern dredging and sluicing plants to the extent of about three-quarters of a million dollars a year.

A line drawn due west from Dawson strikes the Richardson Highway in Alaska about 90 miles southeast of Fairbanks. It is in general along this line that the final connection between Dawson and Fairbanks is expected to be made. From Dawson to the meridian that forms the boundary between the Yukon and Alaska there is a low-type wagon road, about 65 miles long, used mostly in winter, leading to the gold fields on Fortymile River. West of this section is a short stretch of trackless country in which no development has occurred and of which little is known as far as resources are concerned. However, in 1931 a tentative road location was explored by Donald MacDonald, locating engineer for the Alaska Road Commission. He reported that the region presented no unusual difficulties and that there were areas along it that were very promising both for quartz and for placer gold. The distance from Dawson to Fairbanks by this route is about 339 miles, of which there are now 90 miles of good road in Alaska and 65 miles of poor road in the Yukon. Fairbanks by this route is about 2,204 miles from Vancouver.

Dawson, Yukon Territory, Canada, at the Junction of the Yukon and Klondike (Foreground) Rivers

Several variations of the Dawson-Fairbanks connection have been studied but are less encouraging than the direct east-and-west line. The reconnaissance also developed several possibilities for a connection between the Richardson Highway and Whitehorse without following the Yukon River and its branches. The most promising of these would make use of a low-type road westward from Whitehorse for about 125 miles to Kluane, in the Yukon Territory, and a branch road now under construction extending eastward to Chisana from the Richardson Highway. The gap between the two ends amounts to only about 180 miles. This location has the advantages of least distance of new road to be built (about 200 miles less than the Dawson route), easy construction, moderate elevations, encouraging possibilities of mineral development, favorable climatic and topographic conditions, and superior scenic attractions. It has the disadvantage that it fails to include Dawson, the capital of the Yukon Territory, and thus may not be favored with enthusiastic local support in that territory.

The backbone of the road system in Alaska, with which the international project would connect, consists of the Richardson and Steese highways, joining the north Pacific coast port of Valdez with the Yukon River at Circle. It is of interest to mention in passing that Valdez is said to be the northernmost ice-free all-year port in the world. Its latitude is 60°36′ N. The Richardson Highway cuts through two important mountain ranges between the coast and the Yukon Valley. Although the northerly range contains the highest mountains of North America, including Mt. McKinley, the very highest, the pass is at the relatively low elevation of about 3,310 ft above sea level.

Fairbanks is the northern terminal of both the Richardson Highway and the Alaska Railroad. This railroad is a Government-owned line extending south to Seward, a Pacific Coast port about 150 miles west of Valdez. The Steese Highway, 163 miles long, connects Fairbanks with the Yukon River at Circle—so named because of the early belief that the town was on the Arctic Circle. Actually it is about 50 miles south of the Circle. The Richardson and Steese highways, with their branches and connections, comprise over 900 miles of road.

The Richardson Highway, 371 miles long, is a typical example of a road built to meet the needs of a pioneer population. The first improvements consisted of rough grading where essential, of bridges over small streams, and ferries on the larger ones. Many miles of open country and creek beds were used as a roadway with no surface at all other than that developed by the wheel and hoof tracks of traffic itself. As each obstacle or impediment was overcome, the next most important one was tackled. Improvements were made progressively until finally the entire route was traversed by a graded, surfaced, and drained roadway. About $8,000,000 has been spent on it up to 1934, covering all expenses of construction and maintenance during nearly 25 years—about $21,000 per mile. In good weather it can be traveled comfortably at an average of 30 miles per hour.

In its entirety the highway is open from five to six months of the year. Parts of it—particularly in the interior—are used the year around, but in the mountainous section and near the coast the snowdrifts reach such depths that the maintenance of winter traffic is inadvisable. The railroad, however, is kept open for continuous year-round service although the frequency of trips is greatly reduced in winter. In former days communities in the interior not directly served by the railroad received their winter freight and mail by wagons, pack horses, or dog sleds, but in these modern days mail and light freight are carried by airplanes.

Cost Estimates

Costs for the various sections of the highway have been estimated on the basis of the known normal costs of similar construction in the various localities. A more accurate estimate cannot be made of course until the location is definitely fixed and the quantities estimated. However, the estimates here given are based on the experience of highway engineers on road work of similar character and are reliable for purposes of approximation.

In general the estimates contemplate a graveled surface 16 ft wide on a graded roadway 24 ft wide, with perhaps narrower sections where the work is heavy, including all needed ditches, culverts, and bridges except at a few of the larger crossings, where it is assumed that ferries will be employed initially. On this basis the estimated cost of the project, subdivided by territorial limits, is:

THE RICHARDSON HIGHWAY NEAR THE SUMMIT OF THE COAST RANGE
On the 370-Mile Route from Valdez to Fairbanks, Alaska; Worthington Glacier in Background

Section in British Columbia	$7,310,000
Section in the Yukon Territory	4,680,000
Total section in Canada	11,990,000
Section in Alaska	1,970,000
Grand total	$13,960,000

Financing is not only one of the most important questions connected with this project but unfortunately the most perplexing. The sources available for road construction in any locality are also available for this project in part, but what proportion can be furnished from each source and what new sources can be found will only be determined after further study by the responsible agencies.

Local contributions, meaning those by the people living along the route, either in work or funds, can be expected to account for only a small part of the mileage. However, by incorporating short sections to be built or already built by local agencies it is expected that substantial gains in mileage will be attained.

After years of experience gasoline and oil taxes have been found to be the most practicable sources of revenue for road improvement. There is no reason to believe that any better method of deriving a part of the cost of this project from those who use it can be found than to dedicate the tax paid on fuel and lubricant sold at stations along the route to the purpose of paying for the road itself. Since no revenue of this kind can be obtained from any section of road prior to its improvement to a usable condition, provisions would necessarily have to be made for the advancement of funds for current construction costs as well as for repayments from future tax yields as far as practicable.

Aside from possible local sources of funds, including revenue from the road itself, the only other possible source is government aid. Such aid is of course no innovation either in Canada or the United States. Without it the splendid trunk highway systems now in existence would never have been built. Similarly, the Alaska–United States project may be expected to be only a paper project until government assistance from both countries is forthcoming.

The leading national interest in the project is in the development of outlying areas which, although they possess important resources, now lie fallow because they are insufficiently prospected and difficult of access. Such resources now existing in British Columbia, the Yukon, and Alaska will be uncovered and tapped by this route. The touring and recreational phase involves benefits akin to those incident to the use of National Parks, which both in Canada and the United States are considered worthy of large expenditures. The resulting stimulation of motor and other industries and the development of business in supplying and accommodating tourists are not to be ignored. The inhabitants of the territories involved in the project are of course vitally interested in the advancement of their interests which it will afford by giving them access to neighboring areas and to the United States and Canada generally.

In addition, aviation would be greatly benefited by the road. It so happens that the route is a favorable air channel in that it is free from many of the flying hazards encountered along the coasts of British Columbia and Alaska such as bad flying weather, frequent fogs, and often hidden mountains. Along the route of the proposed road there are less rain and fog than on the coast, and there are practical landing places at convenient intervals for both pontoon and wheel-type planes. The road would be a suitable axis of supply for airplane travel, affording means of transporting everything that is needed for the operation and repair of planes, the shelter and accommodation of aviators and passengers, and relief in case of forced landings. Moreover, this road, extended westerly through Alaska, follows the most practicable air route to Asia, which it is not unreasonable to expect that air commerce may some day develop.

That this highway will further cement friendly relations between the citizens of Canada and the United States, resulting in increased trade between the two countries and greater solidarity of their peoples, needs no demonstration. The project fits suitably into the comprehensive road system which it is hoped will one day unite all the Americas.

In conclusion it may be said that the project is feasible from an engineering and construction viewpoint, that it can be built at reasonable cost, that it will produce important benefits, and that it is in keeping with the generally accepted course of development of the continental highway system.

Salvage of Sewage Studied

Joint Committee of the Sanitary Engineering and Irrigation Divisions Reports Definite Progress

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On December 4, 1933, the Committee on Salvage of Sewage rendered a progress statement to the Sanitary Engineering and Irrigation Divisions, setting forth in general its intention to pursue its investigation to the end that it might report on the comparative value and cost of production of water, fertilizer, fuel, and grease from sanitary sewage and industrial wastes. This progress report was presented to the Sanitary Engineering Division at the Annual Meeting in New York, N.Y., on January 18, 1934. It indicated a subdivision of the main topic into nine subtopics, each assigned to a member of the committee for investigation and report. The nine subtopics comprehend a development of the values and cost of production of materials to be salvaged from sewage as well as the legal and health aspects involved in their use. It was stated at the time the report was given that no progress of interest could be expected prior to the Annual Convention in July 1934. The present report, presented before the Sanitary Engineering Division on July 12, 1934, at the Annual Convention in Vancouver, deals with the progress made since December 1933. The other members of the joint committee are Earnest Boyce and R. R. Lyman, Members Am. Soc. C.E., and R. F. Goudey and E. A. Reinke, Associate Members Am. Soc. C.E.

On March 5, 1934, at the suggestion of Mr. Reinke of the committee, there was mailed to the Director of Public Health of each of the 48 states and the District of Columbia, a questionnaire, the answers to which would indicate the extent of sewage use for irrigation in each of the states, the influence of such use on the public health, and the standards that should be prescribed and enforced if water and fertilizer reclaimed from sewage are to be used in the production of foodstuffs to be eaten raw, to be cooked, to be used as fodder crops, or to be used in the irrigation or fertilization of public grounds. The questionnaire also attempted to sound out the degree of willingness of state health officers to permit the use of reclaimed sewage products.

Replies to Questionnaire Received

As of June 26, 1934, replies to the questionnaire had been received from 39 states and the District of Columbia. Of these states, 9 admit having had experience with sewage irrigation and sewage-irrigated crops. Four of the nine health officers are able to trace illness of an epidemic order to such use, the nature of the illness, and the circumstances surrounding the investigation, indicating without question a sewage pollution of foodstuffs for human consumption. One state, through its state health officer, describes an experience in which cattle, pastured on raw sewage-irrigated fields, developed poorly and were infected with a disease that rendered the meat unfit for human consumption. Four states that have had experience with sewage irrigation indicate no difficulties, probably because of the manner of irrigation and the nature of the crops affected.

Intestinal Disease Noted

In one state sewage is discharged raw into streams, and later the polluted water is diverted for irrigation use. In this locality the incidence of intestinal disease is high where such water is used for irrigation, and the health officer believes that no crops grown within a foot of the ground surface should be irrigated with sewage-polluted water. Because of the many places in the arid sections of the country known to be using sewage-polluted waters, the committee is considering a standard for irrigation water. The committee is concerned with the salvage of irrigation waters, which without rectification are liable to so pollute garden truck as to render it unsafe for consumption.

In the nine states that admit experience with sewage irrigation, the attitude is one of tolerance for the act and rigid regulation of the production of the effluent, as well as of the nature of the crops for which it is to be used. From an esthetic standpoint, the use of prescribed effluents is tolerated or approved. There would be no objection to a dual water system, one carrying domestic water and the other reclaimed sewage water, provided that rigid regulations surround the installation of the latter and that cross connections to the domestic supply are prohibited. Opinion as to what authority should enforce the regulations is divided as follows: four are in favor of control by state authorities; two advocate control by local authority; and three suggest a dual control, with state authority in a supervisory capacity.

Summarizing the results in these nine states, it may be said that experience has indicated that the procedure may be so planned as to eliminate menace to health and public nuisance. It is interesting to note that only one state of the nine is agreeable to the use of a prescribed standard of effluent on vegetables to be eaten raw. This state has set up a standard which prescribes that the water so used must be "well oxidized, non-putrescible, and reliably disinfected or filtered" and must always meet "the following bacterial standard: in any 20 consecutive samples, from which five 10-cu cm portions each are examined, not over 10 portions shall be positive for members of the coli-aerogenes group, and in no single sample shall over half the 0.1-cu cm portions of the sample of the effluent be positive for the above organisms." This is the bacteriological standard for drinking water.

Sewage Irrigation Not Tolerated in Many States

Of the states, 30 reported that there was no sewage irrigation or other use of sewage-polluted waters within their boundaries. A number declined to express any opinion whatsoever, and 17 would not tolerate the use of sewage for irrigation. The rest found the idea of sewage irrigation repugnant. In only one instance was there no objection to it. All 30 states were opposed to a dual water system, although practically all agreed that such a system could be so safeguarded as to eliminate danger in

indiscriminate use. One state reported that sewage effluent of any character should not be used on vegetables that are eaten raw. However it stated that for vegetables to be cooked, for fodder crops, and for use on parks and lawns, the effluent should be measured by certain standards. For the first two, these standards are an effluent of 30 ppm B.O.D. (bio-chemical oxygen demand); and for the latter, 20 ppm B.O.D.

DOUBT EXPRESSED AS TO EXTENT OF USE

More than half of the states without experience in the use of sewage sludge would prohibit its use in any form on vegetables or fruits to be eaten raw. A number declined to comment, and the rest indicated repugnance to the idea without expressing any definite knowledge of its hazards. Opinion is about equally divided for and against its use on cooked vegetables. The majority express a willingness to use it on fodder crops, and the same holds true for its use on lawns and parks. As to the use of effluent from any type of sewage treatment plant for the same purposes, there is little expression of opinion. The majority decline to comment, and nearly all the rest favor prohibition of such usage. A very few express tolerance or approval.

NEED FOR DEFINITION OF TERM

At its April meeting the committee came to realize that it must come into agreement as to the definition of the term "salvage of sewage." In the absence of specific instruction as to the scope of the investigation, the committee felt that in addition to water and fertilizer, grease and fuel could be salvaged and that these should also be included. An attempt was then made to define the limits of the study. Viewed broadly it seems that under certain circumstances the water from sewage is just as certainly salvaged by natural stream purification aided by the water works as though it had been reclaimed at a sewage treatment plant. Particularly is this true in either of two instances: one where the indication of fecal pollution is so high as to resemble dilute sewage, and the other where total diversions from a stream, used for both water supply and drainage disposal, are greater than the stream flow.

Where waters are so heavily charged with sewage as to render crops dangerous for human consumption, quite obviously their use denotes sewage irrigation. If such crops are turned to profit, a salvage of sewage has taken place, wrongfully perhaps, but not prohibited. Thus the term "salvage of sewage" may be construed to cover not only the reclamation of certain products of value produced at the sewage treatment plant, but also within rational limits the re-use of sewage water rendered fit by natural purification plus extraordinary water-works treatment.

If the latter may be defined as a "salvage of sewage," then the committee feels inclined to include in its report the advantages or disadvantages of assisting more comprehensively in the salvage by the erection and operation of more efficient sewage-treatment plants, leaving less of the job to the water works. Studied comprehensively from this viewpoint, the elimination of gross stream pollution may develop interesting factors. Dilute sewage and gross stream pollution are practically synonymous, and the fine demarcation that differentiates between some water-works plants and some sewage plants is not readily distinguishable.

MAPS OF RIVER POLLUTION NEEDED

The committee is now planning to request from state health authorities a map of each state, which will indicate the extent to which rivers used for water supplies are also used for sewage disposal. Such a map prepared for the state of Kansas, by Mr. Boyce of the committee, will be used as a specimen to indicate the information desired. From such data the committee may be able to detect a somewhat universal re-use of sewage water little suspected at the present time, and to fortify the position of those who seriously contemplate a direct re-use of sewage products.

ADVISORY SUBCOMMITTEE APPOINTED AND CANVASSED

As an aid to the five committee members, to advise and assist in the work, the following have agreed to constitute a subcommittee: Sidney T. Harding, Charles H. Lee, H. W. Streeter, and F. H. Waring, all Members Am. Soc. C.E.; Wm. E. Stanley, and J. S. Whitener, Associate Members Am. Soc. C.E.; and Frank Adams, L. V. Wilcox, V. M. Ehlers, and E. S. Tesdale. This advisory subcommittee was canvassed on the following four questions:

1. Do you consider that the complete purification or rectification of a domestic water supply taken from a sewage-polluted stream or other body of water should be classified as salvage of sewage?
2. Does your answer to the foregoing depend on the degree of pollution?
3. If so, and if you can visualize, or if you have knowledge of a condition where the rectification of a water supply might be analogous to the salvage of a sewage end product, what would you define as a degree of sewage pollution, less than which the rectification of a water supply therefrom might be considered water purification and more than which might classify it as sewage salvage?
4. In your opinion, if sewage is treated prior to discharge into a stream or other body of water, in order that such water may be protected from pollution and rendered fit, with moderate treatment, for domestic consumption—does such treatment constitute a salvage of sewage?

According to the seven replies, some are inclined to consider that the purification of sewage-polluted water is sewage salvage; others that it is not. The degree of pollution measures the difference, according to certain members, while to others it has no significance. So far no opinion has been advanced that will draw a clear line between sewage salvage and water purification, although Mr. Goudey, of the committee, expresses the thought that where B-coli counts of 1,000 per cu cm or over are encountered in the raw water supply, water-treatment plants are not sufficient to cope with the situation. The extraordinary treatment involved in the production of a potable water from such source involves the use of sewage-plant features preliminary to, or in addition to ordinary water works.

AIMS OF THE COMMITTEE

Opportunity is taken here to express appreciation for the thought and effort given the subject by the subcommittee members, who on very short notice expressed experienced opinion on the perplexing questions. During the next few months the committee hopes by agreement to define the limits of its study and to prepare a more statistical report for the Annual Meeting of the Society in January 1935.

The committee holds no brief for the "salvage of sewage." It intends to indicate generally and specifically, if possible, where and how "salvage of sewage" takes place; what has been accomplished and what may be accomplished in the modern sewage-treatment plant; and what probable cost and utility may be anticipated for the several end products.

The Fort Peck Project

Mammoth Earth Dam on Upper Missouri River Primarily for Control of Navigation and Floods

By Theodore Wyman, Jr.

Captain, Corps of Engineers, U. S. Army; Assistant to the Division Engineer, Missouri River Division, Kansas City, Mo.

In Northeastern Montana a huge construction project that will cost $86,000,000 is now under way. This structure will dam the upper reaches of the Missouri River and equalize the flow so as to minimize disastrous floods on the one hand and benefit low-water navigation for 800 miles along the lower river on the other. Captain Wyman presents a graphic picture of the present and the future work. Geological as well as geographical conditions dominated the choice of site and materials of construction. To obtain a crest height about 250 ft above the present river, an earth-fill dam 8,800 ft long, with an average base width of 2,700 ft, is needed, supplemented by over two miles of earth dike. Provisions for hydraulic sluicing, for by-passing the river, and for passing floods over the spillway are on a corresponding scale. It was even necessary to provide 285 miles of heavy electric transmission line exclusively for the job. This account is abstracted from a paper presented before a joint meeting of the Highway and Construction Divisions on July 12, 1934, at the Annual Convention of the Society in Vancouver, B.C.

In an era noted for its great dams, the Fort Peck Project takes rank with the largest, as a brief summary of its characteristics will indicate. The capacity of the reservoir is 19,500,000 acre-ft at pool level; its length, approximately 185 miles; its greatest width, about 17 miles; and its surface area, 245,000 acres. The construction features consist of an earth dam, with a main section between the river bluffs 8,800 ft long and a low levee section approximately 11,000 ft long located on the left bluffs, with a maximum height above the river of 247 ft; a masonry spillway with a normal discharge capacity of 254,000 cu ft per sec; a concrete-lined spillway discharge channel 6,300 ft long; four tunnels with diameters of 26 ft and a total length of approximately 24,000 ft for stream diversion purposes during the construction period and for reservoir operation after construction; and an initial power installation of 50,000 hp. The estimated cost of the project is $86,000,000. To date (July 1934) $50,000,000 has been allotted for the work.

In the course of studies of the potentialities of streams in the Missouri River Basin authorized by House Document No. 308, 69th Congress, 1st session, and Section 10 of the Flood Control Act of May 15, 1928, investigations

Table I. Lengths and Drainage Areas of Main Stem of Missouri River

Station	Length of Main Stem Above Station (Miles)	Total Drainage Area Above Station (Square Miles)
Cascade, Mont.	157.9	18,046
Great Falls, Mont.	216.2	22,994
Fort Benton, Mont.	261.5	24,570
Above mouth of Marias River	283.4	24,900
Above mouth of Judith River	349.7	36,190
Above mouth of Musselshell River	469.7	42,170
Fort Peck Dam site	595.7	57,725
Above mouth of Milk River	607.0	57,810
Above mouth of Yellowstone River	783.7	93,760
Williston, N. D.	820.2	164,530

of the Fort Peck Reservoir were made by the U. S. District Engineer, of Kansas City, Mo. His report recommended the construction of the Fort Peck Reservoir as an essential part of the adopted plan for the ultimate utilization of the water resources of the Missouri River Basin, and especially in connection with the improvement of the Missouri River for navigation between Sioux City, Iowa, and the mouth of the river, a distance of approximately 800 miles. The immediate construction of the Fort Peck Reservoir (Fig. 1) was recommended by the Chief of Engineers, U. S. Army, in a report to the Secretary of War on September 30, 1933, and the project was authorized by the Federal Emergency Administration of Public Works. An allotment of $25,000,000 was made October 10, 1933, and construction commenced ten days later. Rapid progress has been made in the construction, approximately 7,000 men having been employed at the site during July 1934.

The Missouri River Basin (Fig. 1) is formed by the junction of the Jefferson, Madison, and Gallatin rivers known as "The Three Forks" near Gallatin in south-central Montana. From there to its mouth it has a total length of 2,470 miles, with a total drainage area of 530,000 sq miles, of which 9,700 are in Canada. Data on the length, area, and slope for the part indicated in Fig. 1 are shown in Tables I and II.

The region occupied for the Fort Peck Reservoir is sparsely settled, a large area of it being part of the public domain. It contains no towns, railroads, surfaced highways, bridges, or important improvements.

The stream is quite free of sediment. Below the mouth of the Milk River, however, it transports a heavy load of silt. During a normal year as much as 250,000,000 tons pass Kansas City, Mo. Silt studies of the Missouri River above the Fort Peck Dam site indicated that the deposition in the reservoir will be at the rate of 225,000 acre-ft per 100-yr period.

Pertinent discharge data on the Fort Peck Dam in-

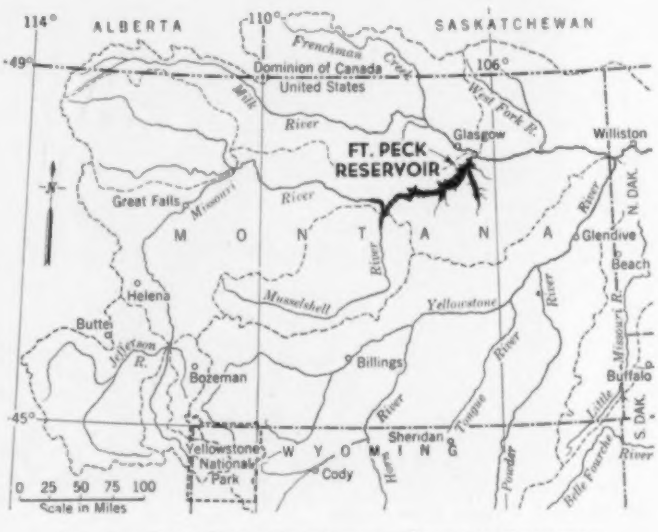


Fig. 1. Fort Peck Reservoir—General Location

clude the following: mean annual discharge, 8,253,000 acre-ft; mean daily flow, 11,400 cu ft per sec; mean

TABLE II. SLOPE DATA ON LOW-WATER STAGES OF THE MISSOURI RIVER

Miles Above Mouth in 1890	Locality	Date 1889	Elevation	Slope (Ft per Mile)
2,546.3	Head of river	....	4,026.0	4.27
2,384.0	Head of Long Pool . . .	....	3,333.6	0.44
2,333.4	Great Falls (foot of Long Pool)	....	3,311.3	..
2,322.0	Foot of the Great Falls .	....	2,898.8	..
2,314.5	Portage Coulee	....	2,758.8	4.81
2,284.8	Fort Benton, Mont. . . .	Sept. 5	2,615.8	2.57
2,155.0	Foot of Cow Island . . .	....	2,282.0	1.04
1,720.1	Williston, N. D.	....	1,828.0	

depth of run-off above the dam, 2.68 in.; and maximum discharge (June 1908), 154,000 cu ft per sec.

WHAT THE PROJECT ACCOMPLISHES

When the Fort Peck Dam is completed, it may be used for the following purposes:

1. Storage in the reservoir of a major part of the annual "June rise" of the Upper Missouri Basin caused by the melting snows of the mountainous region and the heavy run-off from rainfall, which normally occurs during the months of April, May, June, and July.
2. Operation of the reservoir so as to maintain a minimum flow of 30,000 cu ft per sec at Yankton, S.D., at all times during the navigation season (March 20 to November 15), thus maintaining a 9-ft navigation channel from Sioux City, Iowa, to the mouth of the river, a distance of approximately 800 miles.
3. Operation of the top 8 ft of the reservoir for complete flood control of the upper river and, incidentally, for lower flood heights in the Lower Missouri Valley.
4. The generation of power to be used for worthy irrigation pumping projects located in the upper basin and for other purposes.

Incidental benefits will be great, as the reduction of flood heights will make possible the reclamation of thousands of acres of very fertile, contiguous lands and throughout the unimproved river will materially reduce bank erosion, which during a normal year is as great as 47 acres of land per mile of river. The maintenance of a minimum discharge of 30,000 cu ft per sec at Yankton will materially benefit navigation conditions on the Mississippi River below the mouth of the Missouri, especially during the low-water months of September, October, November, and December.

TUNNEL CONSTRUCTION BEGINS
Excavating for Downstream Portals

In the vicinity of the Fort Peck Dam site, general features of which are shown in Fig. 2, the highest parts of the upland rise to elevations of about 2,400 ft, nearly 400 ft above river level. East of the river is a broad belt of shale badlands, drained by the ramifying branches of several ravines, which are dry most of the year. A quarter of a mile from the foot of the bluffs the highest points rise to about 2,350 ft, which is approximately 110 ft above the proposed water surface. Farther back there is a gradual rise of the topography one or two hundred feet more. The left, or western wall of the valley at the site is formed by the end of a broad spur of the upland.

Eastern Montana is underlain by a series of late Mesozoic and early Tertiary formations. In

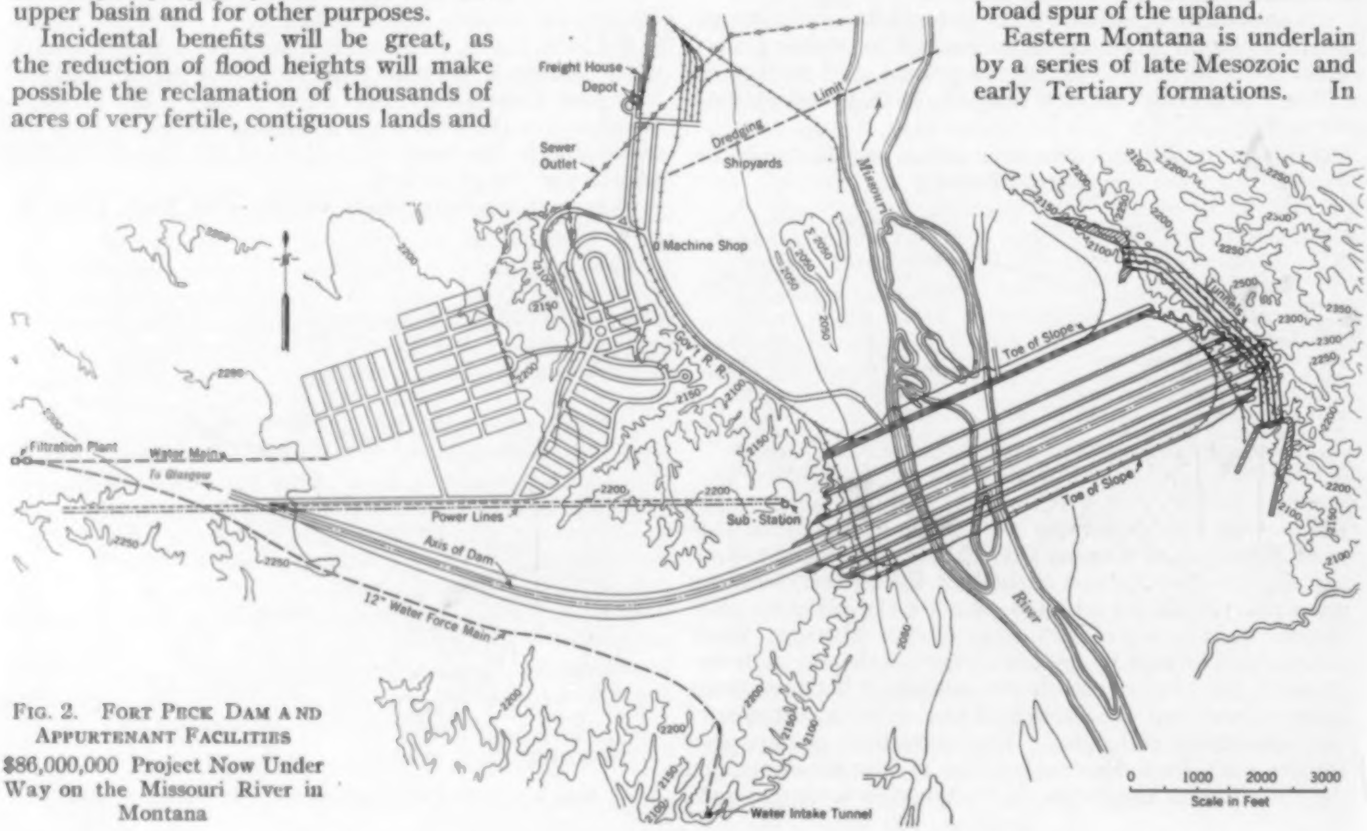


FIG. 2. FORT PECK DAM AND APPURTENANT FACILITIES
$86,000,000 Project Now Under Way on the Missouri River in Montana

general these dip eastward at a low angle. However, this slope is steeper than the general land surface, so that the younger formations are exposed on the east, the older on the west. A combination of gentle, local warpings with the action of the principal streams has produced considerable irregularity of outcrop pattern. Most commonly the outcrops of lower, older formations extend downstream in the valleys for some miles east-

Temporary Traffic Bridge Crosses Missouri River
Railroad Trestle Construction Under Way Alongside

ward from the point where the younger formations appear on the bluffs.

The Fort Peck Dam site is located within the outcrop belt of the Bearpaw shale, which forms the floor of the Missouri River Valley for nearly a hundred miles to the east. Only this shale, among the bedrock formations, is of practical consequence in the construction of a dam at this point.

From the testimony of local wells and the known structure and thickness of the formation, it is apparent that the shale extends to depths as great as 1,000 ft below river level at Fort Peck. The bed of this formation takes a slight regional dip to the east, but for construction purposes it may be regarded as essentially horizontal. It rises to at least 2,350 ft in the right abutment and is exposed throughout the face of the right bluff down to the level of the valley flat. The surface of shale below the flood plain has an elevation of approximately 1,940 ft, with an overburden thickness of from 110 to 120 ft of alluvium.

On the upland east of the site and near the margins of some of the spurs, there is a thin but variable cover of glacial till, with associated gravel lenses. On the west-abutment spur the till occurs at greater depths and is from 80 to 100 ft thick over the western part of this spur, but grows thinner with the lowering of the topographic surface until it is only a few feet thick at the brow of the west bluff.

Below the glacial till and between it and the shale in the western spur is a formation consisting largely of fine and medium sand, which was deposited by the river, possibly during the time of glacial invasion. Little or no gravel occurs in this formation. The alluvium which occurs across the valley flat to depths exceeding 100 ft, consists chiefly of sand with interspersed clay beds, probably derived as wash from the shale bluffs. At the base a few feet of gravel lie immediately on the shale—at least in some places.

The Bearpaw formation consists of nearly uniform clay shale beds of marine origin that are dark gray or black in color. This formation is about 1,000 ft thick and shows little variation from top to bottom. Its weathering is of special interest. The process is promoted chiefly by the wetting and drying incident to exposure at or near the surface. A large number of joints and irregular partings develop as the shale is weathered, resulting along certain outcrops in fairly thin, flat flakes, but more commonly the fragments are rudely flattened and are bounded by irregular oblique and curved surfaces.

This shale possesses a porosity of about 18 per cent. It is a highly impervious formation. Even where it is somewhat weathered it is capable of maintaining a very steep line of percolation. Tests of crushing strength show fairly uniform results. Ten cores about 2.8 in. in diameter and from about $1^1/_2$ to 3 in. high averaged 3,100 lb per sq in. in strength.

As shown in Fig. 2, the Fort Peck Dam is an earth-fill

General View of Fort Peck Dam Site
Railroad, with Yards in Foreground, Leads to River Crossing. Boat Yards on Near Bank of River

structure, with a main section approximately 8,800 ft long between the river bluffs, and a wing on the left side consisting of a low dike approximately 11,000 ft long. The maximum height over the river to pool elevation is 212 ft, and to crest 247 ft, providing a freeboard of 35 ft. The minimum width at the top is 100 ft and the average width at the base is 2,700 ft, with an average upstream slope of 1:4 and an average downstream slope of $1:8^1/_2$.

BUILDING 28-IN. PIPE-LINE DREDGE IN GOVERNMENT SHIPYARD
Wooden Housing, Machinery, and Equipment to Be Added

A rock and gravel fill is provided at both the upstream and downstream toes. Along the axis, from bluff to bluff, a steel piling cut-off wall is being driven through the alluvium to the underlying shale, in order to reduce percolation under the structure. The face of the dam will be paved with durable rock. All objectionable materials, such as clays and deteriorated shale, are being removed from the base of the dam. In the construction of the dam the quantities listed in Table III are involved.

TABLE III. EXCAVATION AND MATERIALS IN FORT PECK DAM

ITEMS	QUANTITIES
Stripping	4,100,000 cu yd
Earth-fill in the dam section	92,000,000 cu yd
Earth-fill in the dike section	6,500,000 cu yd
Rock and gravel fill in the upstream toe of the dam	861,000 cu yd
Rock and gravel fill in the downstream toe of the dam	2,745,000 cu yd
Rock for facing the surface of the dam	870,800 cu yd
Rock in the parapet wall	201,190 cu yd
Gravel for facing the surface of the dam	497,200 cu yd
Portland cement concrete in the parapet wall	246,500 cu yd
Steel sheet piling	1,042,100 sq ft
Excavation incidental to the placing of steel sheet piling	110,700 cu yd

Construction will be by hydraulic methods. An impervious core consisting of fines will be constructed under the axis of the dam, deposited in a manner so that the gradation will vary from fine to coarse both upstream and downstream toward the surfaces of the dam. Excess fines not needed for the impervious core will be wasted. The materials will be taken from borrow pits located in the flood plain both upstream and downstream from the dam.

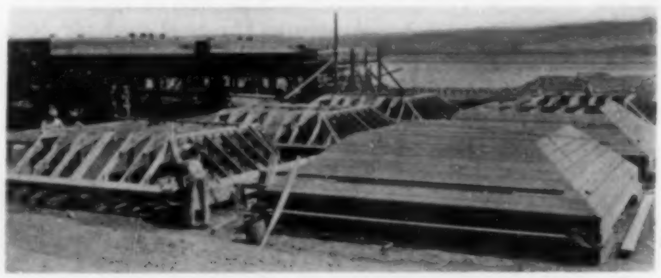
Four dredging units will be used, with a total of approximately 50,000 hp and a capacity of 2,900,000 cu yd per pumping month. Each unit consists of a hydraulic dredge of 28-in. discharge cutter-head type, equipped with two 2,500-hp motor-driven pumps; a booster barge equipped with two 2,500-hp motor-driven pumps; a land booster, consisting of a 2,500-hp motor-driven pumping unit mounted on a car and operated over railroads located at the downstream and upstream toes of the dam; and approximately 12,000 ft of discharge pipe. The pumps are connected in series. Electric power to operate the dredging units will be distributed from the substation at the dam site to the dredging units by means of a 6,600-v feeder system.

Materials for the rock and gravel fills at the toes will be hauled from distant points by standard railroad equipment and dumped in place from trestles now under construction along the axis of each fill. The stripping of the site, and the driving of the sheet-piling cut-off wall are now (July 1934) being vigorously prosecuted. Construction of the rock and gravel fills and dredging operations will be commenced in the latter part of September 1934.

CONTROLLING NORMAL AND FLOOD DISCHARGES

As shown in Fig. 2, four circular tunnels, with 26-ft diameters and a total length of 24,000 ft are being constructed through the right bank of the Bearpaw shale bluffs. The first operation consists of driving an 8 by 12-ft pilot tunnel, enlarging the bore to full section, and placing the concrete lining. The second operation comprises grouting in place of a steel lining consisting of a $^3/_4$-in. to $1^1/_4$-in. steel plate and placing of the interior concrete lining. The control is accomplished by means of four 50-ft circular shafts approximately 250 ft high, located near the axis of the dam and lined on the outside with reinforced concrete and a steel shell 1 in. thick. Interior shafts also of reinforced concrete and a steel shell will be equipped with two sets of suitable ring gates at various elevations. The total discharge capacity of the four tunnels with the shaft control at full head is approximately 85,000 cu ft per sec.

Bearpaw shale deteriorates when permitted to dry. Therefore in the tunnel construction all shale surfaces are promptly coated with a protective solution, and concrete is placed within 20 days. In an experimental tunnel, shale surfaces thus treated show no signs of deterioration after six months of exposure. Bearing tests conducted on the floor of this tunnel indicate that pressures as great as 90 tons per sq ft create no appreciable deformation of the shale. During careful observations on the experimental tunnel over a period of six months, no movement, swelling, or distortion has been detected.



BUILDING PONTOONS RAKED FOUR WAYS FOR USE AT ANGLES IN THE PIPE DISCHARGE LINE
Scows and Launching Ways in Background

The greatest flood of record at the dam site occurred in 1908, with a peak discharge of approximately 154,000 cu ft per sec. The length of the river above the dam site is 596 miles, with a drainage area of 57,725 sq miles, an average annual precipitation of about 15 in., and a mean and maximum annual run-off of 2.68 in., and 4.08 in., respectively, for a period of 43 years.

A study of flood probability, using the method advocated by the late Allen Hazen, M. Am. Soc. C.E., indicates maximum floods as follows: 100-year period,

160,000 cu ft per sec; 1,000-year period, 285,000 cu ft per sec; and 10,000 year period, 464,000 cu ft per sec.

The theory of probabilities was not considered reliable for spillway design. Instead, the following combination of factors was assumed: (1) abnormal precipitation in September just prior to the advent of freezing temperatures; (2) a severe winter of continued cold weather accompanied by sharp thawing periods and abnormal snowfall; (3) a late spring accompanied by sharp periods of thaw and a normal amount of precipitation of sufficient quantity to consolidate and saturate the snow blanket, followed by a long sustained period of high temperature; and (4) a rainstorm of high intensity, falling in such a manner as to synchronize with the period of high run-off from melting snow. This study indicated a maximum daily discharge of 360,000 cu ft per sec for this hypothetical flood.

Studies of operation of the Fort Peck Reservoir based on records of flow indicate that when used for straight navigation benefits, during the period from 1890 to 1933 inclusive, the reservoir would have spilled, for portions of 27 of the years studied, as much as 7,900,000 acre-ft in a single year. When operated as a combination flood-control and navigation reservoir for the same period, it would have spilled once in the 44 years with a maximum discharge of about 50,000 acre-ft.

As a result of these studies, a spillway with a discharge capacity of 254,000 cu ft per sec at normal pool elevation was tentatively adopted. When this spillway is operated in connection with the tunnels, it will furnish adequate discharge capacity to meet the conditions of the adopted hypothetical flood.

The spillway is beyond the limits of Fig. 2, in the right bank of the Bearpaw shale bluffs, approximately 12,000 ft distant from the right abutment of the dam, with an outlet about 41,500 ft downstream from the toe of the dam. It is a masonry structure about 850 ft wide, supporting 17 Stoney gates, 25 ft high and 40 ft wide; an approach channel, 850 ft wide excavated in the Bearpaw shale; and a concrete-lined spillway channel, approximately 5,100 ft long, of varying width, and terminated at the low-water elevation of the river by means of a concrete masonry cut-off wall. The fall in the spillway channel is from elevation 2,225 to elevation 2,040.

The initial power installation will be for approximately 50,000-hp capacity. The ultimate installation will be 400,000 hp.

CONSTRUCTION FACILITIES PROVIDED

It became necessary to construct 28 miles of standard railroad to connect with the main line of the Great Northern Railroad at Wiota, Mont., and to provide sidings, yards, and a construction track at the site. This included one steel bridge, across the Milk River, consisting of three 100-ft through girder spans; another steel bridge 2,365 ft long, across the Missouri River; and approximately 5 miles of timber trestle for approaches to the Missouri River Bridge and for construction purposes.

A boat yard employing over 500 men was necessary for the construction of the dredging units and other items of floating plant. Because of the remoteness of the site from large cities, the construction of a modern town to house 6,000 men was necessary (Fig. 2). This construction consists of barracks and mess halls, 250 detached houses, an administration building, a hospital, a school, an employees' hotel, a block of stores, a moving-picture theater, a refrigerating plant, a laundry plant, a commissary plant, a modern water supply and sewerage system, 10.7 miles of improved roads and streets, and an 8-in. natural gas line from Glasgow, Mont., to the camp, and a distribution system. An improved highway from Glasgow is being constructed by the State of Montana.

Electric energy generated by the Rainbow Plant of the Montana Power Company near Great Falls, Mont., will be transmitted to the site by means of a 154,000-v power line, 285 miles in length, with a 60,000-kw capacity, now (July 1934) under construction and scheduled for completion in September 1934. A 1,000-hp, 50,000-v power line was constructed from Glasgow to the site for use during the preliminary construction period.

As now contemplated, the plan of operations provides for completion of the Fort Peck Project in five years.

AERIAL VIEW OF CONSTRUCTION HIGHWAY AND RAILWAY TRESTLES OVER THE RIVER CONNECTING WITH CONTRACTORS' PLANT

Treatment of Pacific Coast Water Supplies

Experiences with Certain Troublesome Constituents in Surface and Well Waters

By Jeptha A. Wade, M. Am. Soc. C.E., *and* Kenneth W. Brown

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Water for domestic purposes must be such that it will not be injurious to health. In the West, however, the sanitary control of water has not yet become a serious problem, because the gathering grounds are generally thinly populated. In spite of this fact, certain chemical constituents in Pacific Coast waters often render them unsatisfactory by imparting a taste or odor to them, or by making them unpleasant to the sight or unsatisfactory because of hardness. Certain combinations deposit encrustations in the distributing pipes, thereby reducing their capacity. Other combinations may be extremely corrosive. From their experience with water from both surface and underground sources, the authors of this article, which has been abstracted from a paper presented before the Sanitary Engineering Division on July 12, 1934, during the Annual Convention of the Society, report how certain of the problems that give water works engineers trouble have been met and overcome in the states of Washington, Oregon, and California.

As a rule, the water supplies along the Pacific Coast contain no chemical constituents that cannot be satisfactorily handled by the usual methods of treatment. In California there are 24 plants employing filtration and a few others that use either the coagulation or aeration method, but the great majority of both surface and well supplies are served without treatment.

Hydrogen sulfide as a natural constituent of the water is present in only a few supplies. Aeration with simple and inexpensive equipment usually accomplishes satisfactory removal of this gas and is probably the most economical method to employ. Under certain conditions where no other treatment is necessary and aeration involves the installation of storage as well as double pumping facilities, it may be found more economical and equally satisfactory to use chlorine as an agent of removal. The chlorine, reacting with the hydrogen sulfide, destroys the latter completely, forming other harmless compounds that do not contribute to the taste or odor of the water.

There are some cases, however, of wells which have shown no indication of hydrogen sulfide when they were first put into service, but which later have developed this trouble to a marked degree. Instances of this sort may indicate the presence of beggiatoa, which produce the hydrogen sulfide by attacking and breaking up other sulfur compounds which, except for such bacterial action, would pass unnoticed. It is advisable to have water in which hydrogen sulfide develops examined microscopically to determine whether these organisms are present, because if they are, the clearing up of the water is less simple, and additional treatment will probably be required. Even this situation may be controlled with chlorine. However, it may require such a heavy dose that other disagreeable tastes will result, making the problem one for special consideration and treatment.

Special Problems Encountered

A certain well had been in service only a few months when the water began to appear somewhat milky. This condition grew steadily worse until a sample drawn from a tap at the well showed an amazing quantity of gas which left the water very rapidly. Analysis revealed this to be methane. No other new developments were apparent at that time, and it was decided to build an aerator. Although it was thought that the problem was solved, the aerator had not been in service long before the odor of hydrogen sulfide could be detected in its vicinity, and the bottom of the aerator tank soon showed a black, malodorous deposit. Examination disclosed the same deposit in the mains in the vicinity of the well, and a chlorinator was immediately installed. This has helped conditions to quite an extent, but there have been complaints both of the chlorine and of other tastes and odors. Furthermore, it is necessary to give this plant constant attention, regulating the chlorine feed and blowing off mains in order to keep the situation under control. The present arrangement is anything but satisfactory, and the final solution may be filtration or even abandonment of the source.

Compared with conditions in the Middle West, iron does not constitute a special water-supply problem in the Pacific Coast region. Only a very few plants have been built with iron removal as their principal object. These have taken the usual form of aeration and sedimentation systems, with or without a coagulant, but they have not always been completely satisfactory. At Burlington, Wash., for example, aeration and the small dose of lime which was used, precipitated only a small percentage of the iron, removal being effected almost entirely within the filter bed, which had to be renewed every year. Even so, the reduction was only from 4 to 0.6 ppm on the average, resulting in a water that was not up to the standards of the U. S. Treasury either as to iron or color.

Laboratory experiments showed that complete removal, mostly by sedimentation, could be effected by more complete aeration and more liberal use of any of several coagulants. However, it was found that a cheaper solution would be to abandon the wells and connect the supply line to a river source.

California differs somewhat from Oregon and Washington in that it may be characterized as a hard-water state. About one-third of all its supplies show, in at least some of their sources, a total hardness in excess of 200 ppm; and two wells, used for irrigating golf courses, are on record with a total hardness of 1,495 and 2,500 ppm, respectively. However, not many sources show more than 500 ppm, and many supplies in the state are extremely soft. At the Beverly Hills municipal plant it was only after various attempts to remove hydrogen sulfide had been made by means of aeration, chlorination, and filtration with alum that it was found that lime was necessary for satisfactory operation of the filters. Consequently the plant, as finally built, included facilities for softening as part of the treatment process, and the water is now softened from 275 ppm to 160 ppm.

At its Contra Costa plant the California Water Service Company impounds water from the Sacramento River during the flood period when the salinity is low, and filters and distributes it during the remainder of the year. It has usually been possible to obtain water with an average hardness below 100 ppm to fill the reservoir. Ordinarily this supply is not sufficient to meet the full demands on the system, and late in the season it is necessary to mix this filtered reservoir water with a supply secured from wells that have a hardness ranging from 230 to 300 ppm.

To maintain a fairly uniform water a zeolite softening plant was built. This consisted of two wooden-tub gravity filters, containing 18 in. of graded gravel and 24 in. of zeolite, or 200 cu ft of zeolite in each tub. A single, low-head pump is used, both for putting the water into the filters and also for rinsing after regeneration. Salt for regeneration is received in carload lots on the plant siding and unloaded directly into a wooden tub, where it is dissolved. The saturated brine is then pumped from this tank into a wooden measuring tank located above the elevation of the filters. The plant can operate at a rate of 800 gal per min, and can soften to zero about 800,000 gal per day. Thus it is out of service for regeneration approximately 30 per cent of the time. It has been used as much or as little as necessary, the extent of its use being based on the mixed output of the wells, the softener, and the filter plant, in which the hardness is maintained constant at from 125 to 130 ppm.

REMOVING COLOR

Speaking of the region as a whole, there are a few instances where color constitutes a problem, although no such concentrations occur as are found in some other localities. As a rule, both the well and surface supplies are low enough in color to eliminate the necessity of considering this factor, although there are one or two notable exceptions. The wells supplying the cities of Long Beach and Wilmington, the latter now a part of Los Angeles, are unique in this respect. They penetrate a prehistoric peat bed at least 550 ft thick, which has been buried under about 350 ft of more recent deposits. The water differs materially from that in the surrounding wells in that it is soft and carries a high organic content, together with hydrogen sulfide and a color of from 100 to 125 ppm. Some years ago experiments were inaugurated at Wilmington to determine a method for treating this water because of its undesirable color and the additional fact that the organic content was unstable, causing turbidity and bacterial growths with accompanying offensive odors. An experimental plant, which developed many novel features, was constructed. Using this plant as a model, a 5-mgd plant was built and has now been in operation for some time. The City of Long Beach provides continuous chlorination to combat the hydrogen sulfide, but does not correct the color of the water.

In Oregon a number of small coastal streams in the timber belt are quite highly colored. In spite of this fact, one of them has been used as a source of public supply for many years. Previous to 1925 this water was served without treatment, but its corrosive nature and its organic content caused clogging of service facilities and gave a great deal of trouble. This plant, which is now known as the Coos Bay Plant of the Oregon-Washington Service Company, serves about 10,000 people in Marshfield and North Bend, Ore. The supply is obtained by impounding Pony Creek, which drains an area of about 7 sq miles of cut-over timber land, with a heavy ground covering of decaying vegetable matter from which color is imparted to the water. The water is soft, without turbidity, and free from pollution.

New construction at this plant provided chemical feeding apparatus and a battery of six 8 by 20-ft pressure filters. The effluent from the filters was connected to a set of spray nozzles, which discharged over the surface of a clear water reservoir. Under normal conditions the treatment requires about 1.6 grains per gallon of alum and 0.14 grain per gallon of lime. The latter is necessary for the alum reaction, since the alkalinity of the water is only from 7 to 10 ppm. The natural water has a pH value of from 6.4 to 6.6 and a color of from 90 to 170 ppm. The experimental work indicated that for optimum color removal the water should be brought to a pH value of 5.5, and this is accomplished with the alum.

When the rainy season sets in there is a very heavy increase in the color concentration. During the dry period the color seems to accumulate in the ground covering. It is then leached out by the first rain and brought into the storage reservoir. The first time this happened, which was soon after the plant was put in operation, the attendants were entirely unprepared, and for a few days they had considerable difficulty in adjusting the plant to the changed conditions. Such a change had not occurred during the experimental period, and the operator found that the color did not respond to treatment as color normally does. He tried increasing the alum dose and was finally successful in precipitating the color. Before he succeeded in doing so, however, he had to increase the alum dosage from 1.6 to 4.9 grains per gallon. This experience has been repeated in subsequent seasons. However, it is now expected, and proper treatment is provided so that the plant effluent rarely shows a color of more than 10 ppm. The color is largely removed in the floc, a large part of which drops out in the sedimentation basin.

The filtered water has a pH value of about 5.5 and contains some carbon dioxide and dissolved oxygen and, consequently, is even more corrosive than the raw water. To correct this condition the water undergoes a second treatment with lime. Corrosion difficulties have been practically eliminated from this supply, and the appearance and general character of the water now leave little to be desired.

PREVENTING INTRUSION OF SALT WATER

In the region around San Francisco and also in the Los Angeles area there has been considerable trouble with well supplies due to the infiltration of salt water. Perhaps the principal cause is the attempt to obtain more water than can be replenished by the rainfall in this territory. Water tables have been progressively lowered until the operating level in the wells is more than 100 ft below sea level at many points. This reverses the natural slope of the groundwater gradient and causes flow from the nearest salt water toward the wells. It is the usual practice for an individual or industry to drill wells without regard to the ability of the region to produce water or to the extent to which the locality has already been developed, and to use such supplies until they fail entirely or until the water becomes salty. In this way many areas capable of producing a limited amount of good water have had their natural supply destroyed for all time, since a well that has once turned salty never recovers.

Equally as serious as overpumping is the presence of abandoned wells and leaky casings, which allow seepage from the upper salty strata down into the fresh-water gravels. A considerable amount of good water is lost in this way due to the abandonment of old wells without

first plugging them, and to the faulty construction of new ones. On the San Francisco peninsula there seems to be a direct connection between the water in the bay and the gravels that are encountered in the upper 75 or 100 ft of earth. The water in these gravels is practically as high in chlorides as that in the bay. Below this depth and beneath clay beds, other gravels are found in which the chlorides are low enough to make the water satisfactory. It has been found that the static head on the water in the lower strata is about 20 ft less than that in the strata nearer the surface. Thus any channel through which water can pass from the upper strata to the lower ones results in a steady flow of salt water down into the fresh-water gravel.

When pumping from the lower gravels to obtain a sample, it was found necessary at times to continue the pumping for as much as two days without interruption. Hourly analyses of the pumped water showed a steady reduction in the chlorides, until they approached the figure representing those normally present in the lower strata. The high concentration of chlorides shown at the beginning of the pumping test was undoubtedly due to salt water from above flowing down through the casing into the lower gravel while drilling was going on and while the sampling pump was being installed. This seems to be proof that old wells should be cleaned out and filled to the top of the ground with cement in order to prevent the destruction of usable wells.

To secure fresh water, the present practice is to sink an outside casing with all joints welded until a depth is reached at which fresh water will probably be found. When gravel is encountered at this depth, drilling is stopped and an air-lift pump installed in the well. Pumping is continued until it is definitely determined whether the water in the gravel is satisfactory. In any case, no provision is made for using the water from this stratum, but the outside casing is pushed through it and landed in the clay underlying the first or possibly second layer of fresh-water gravel. The well proper, which is then started within the outside casing, is usually 4 in. smaller in diameter. The bottom 30 or 40 ft of the outside casing is usually perforated in order to force grout into the hole outside the casing and thus make an effective seal against the downward flow of salt water.

The well is finished by completely filling the 2-in. annular space between the two casings with cement grout. This method provides a solid cement shell around the well from a point below the first fresh-water-bearing gravel to the surface of the ground and will maintain an effective seal against salt water long after the outer casing has disintegrated. It enables the securing of satisfactory well water comparatively low in chlorides and is the best method that has yet been found of handling the problem of salt-water infiltration. Salt cannot be removed from a water supply by commercial means; it must be kept out in the beginning.

CARBON DIOXIDE AND MANGANESE TROUBLES

During the past year the water-supply system in one of the larger California plants has been subjected to careful investigation. This system is supplied from 48 wells, which are distributed over the territory served. For some time there has been a certain amount of trouble from rusty and dirty water and also some instances of bad taste and odor. Examination showed that certain of the wells were infested with crenothrix, and the troubles were attributed to this cause. A portable main sterilizer was provided, and the local crew put to work sterilizing mains in the affected areas whenever their regular duties permitted. Some wells also were sterilized. The complaint of low pressure in some localities was received, and examination of the interior of the smaller mains revealed heavy deposits, which materially reduced their capacity. These deposits were also attributed to the action of crenothrix, which were always found. The process of sterilizing the mains was continued and finally supplemented by a program of cleaning and flushing.

Although a considerable number of mains were thus sterilized and cleaned, complaints of the quality of the

EXPERIMENTAL CASCADE AERATOR REMOVES CARBON DIOXIDE
Reduction from 40 to 15 ppm; Head Loss 4 Ft; Manometer Shown Used on Nozzle Experiments

water continued to come in, and it was decided to make a more thorough investigation. Carbon dioxide was found in a number of wells, and in some cases there were amounts sufficient to cause corrosion. This had not been observed previously, due to the amount of time elapsing before the samples were analyzed and to the fact that samples undoubtedly were given a certain amount of aeration in the ordinary process of collecting. Taste and odor were traced definitely to a single well. One well showed manganese running as high as 1.75 ppm.

The resulting report recommended the abandonment of several wells and the treatment of several others to eliminate carbon dioxide. The production capacity affected by this report was sufficient to create a serious situation, both because of the necessity of meeting the 1934 demands and because of the considerable expenditure involved. Of first importance was the elimination of the source of taste and odor in a well that produced 800 gal per min. After that, it seemed essential that the sources of manganese be eliminated as rapidly as possible, since these wells were causing large deposits in the mains and service pipes. It would be possible, of course, to treat such water for the removal of manganese, but the process is not simple and requires numerous facilities.

Assuming that a new well could be located which would be free from this difficulty, abandonment of the old source of supply would be more economical than attempting to treat the water, since sinking a new well at this locality would cost only about $2,000, exclusive of equipment. This sum would be entirely inadequate for the construction of a manganese treating plant with a capacity equal to that of the well.

Two new wells of from 1 to $1^1/_2$-mgd capacity each were required to take the place of the wells that should be eliminated from the system. This called for a complete examination of the territory to determine the most probable location of satisfactory water. Both of the wells to be abandoned were comparatively new. They would undoubtedly have been located elsewhere had a general study been made and all the facts been known at the time they were put down. Samples were collected from existing wells, well-drillers' logs were obtained, and an intensive study of the locality was made. After all this information had been compiled, it was shown that there were three known locations producing bad taste

and odor. It was further shown that in the interest of low manganese, low carbon dioxide, freedom from taste, and satisfactory yield, an entirely new site should be chosen. Two satisfactory wells were then drilled and put in operation.

The corrosive character of the water in another of the wells resulted in closing up the perforations in the casing, so that the lift was increased and the yield reduced. Such a condition might be due to filling of the well above the water strata, to the clogging of the sand and gravel outside the well, or to the closing of the perforations in the well itself. Some tests were made to determine if possible where the difficulty lay. It seemed evident from them that the perforations had become clogged.

Test of Nozzle Aerator for Removing Carbon Dioxide
Discharge, 29.1 Gal per Min; Head Loss, 11.2 Ft; Reduction in Carbon Dioxide, 40 to 6 ppm

The method that was used to free them may not be in common practice, but it has been found successful. With the pump in place, dynamite percussion caps were lowered into the well and shot with a dry-cell battery. Two caps were used every 5 ft, one each on opposite sides of the pump. Two caps were shot at a time, one 5 ft below the other, and after each shooting the pump was started and operated with a wide-open valve for a few minutes. The whole operation required only a few hours, after which the well was restored to its original capacity. The sharp, speedy vibrations caused by the percussion cap seem to work better than anything else in shaking loose the accumulated scale. The caps used were those known as No. 6, standardized by the U. S. Bureau of Mines to have a detonating effect equivalent to 1 g of fulminate of mercury.

Aeration for Removal of Carbon Dioxide

The problem of dealing with the carbon dioxide has not been completely solved. In most cases wells are located on single building lots where space is at a premium. As a preliminary step toward the aeration of this water, some experiments were made this spring with various types of spray nozzles. The set-up consisted of a pipe connection to the pump at a station where the carbon dioxide averaged about 40 ppm. From this pump about 50 ft of $1^1/_2$-in. hose led to an open space where the experiments could be conducted. From the hose the water passed through an ordinary service meter of $1^1/_2$-in. diameter, a control gate valve, and a short length of pipe to which the various nozzles were attached. Just ahead of the nozzle the pipe was tapped for a manometer connection so that the pressures at the base of the nozzle could be read on a mercury gage. The quantity of water flowing was measured with a stop-watch by taking the time required for 10 cu ft to pass through the meter. The spray from the nozzles was collected at a point about 2 ft below the elevation of the nozzle, and all samples were taken by catching the spray after flow conditions had become stabilized. After a sample had been collected, an immediate analysis for carbon dioxide and for pH value was made while the rate of flow was being changed for the next sample. There was therefore little opportunity for inaccuracies due to changing conditions during the progress of the work. Several varieties of nozzle were tested, but only a single size of each type.

For purposes of comparison a cascade aerator 1 ft long was built, having four steps, each 1 ft high. The reduction in carbon dioxide was measured at each step, and it was found that the greatest reduction occurred in the first, that in the others being progressively smaller. In the four 1-ft steps of the cascade it was found impossible to reduce the carbon dioxide below 15 ppm; whereas it was possible with some of the nozzles to reduce it as low as 5 ppm, although there was a loss in head of 24 ft. What the effect of adding additional steps to the cascade aerator would be was not determined, but other experimenters have found that the limit was a residual of from 10 to 15 ppm.

Within the limits of the experiments, it was found that the cascade is about as effective for the head consumed as the nozzles. The cascade, however, is essentially a low-head device, and the nozzles will only operate satisfactorily at higher heads. Once again, if the results are compared on a basis of gallons per square foot of area required for the equipment, the cascade is in line with the nozzles, since the space requirement per gallon is so much less. Space limitations as well as consumed head must be given consideration, unless an ample catch basin already exists. For removal up to a residual of about 15 ppm the cascade appears to be much more economical.

It must be borne in mind that aeration alone will not solve the problem of corrosion, since the residual carbon dioxide, together with the oxygen dissolved during aeration, may cause the water to be even more corrosive than it was originally. To complete the job the water must be treated with lime or soda ash to neutralize the residual carbon dioxide, and the effect of aeration is simply to reduce the amount of chemical required for this purpose.

Effect of Drought

It seems probable that many localities will experience during the present year one of the most severe droughts on record. All areas in California depending on natural stream flow will be seriously affected, and undoubtedly the low run-offs will be reflected to some extent in many well supplies. The snow pack in the high Sierras had disappeared almost entirely before March 1. Thus there has been no melting snow to feed the streams, and the precipitation has been almost invariably subnormal. Quoting from the U. S. Department of Agriculture's climatological data for California for the month of April, "At the close of April the seasonal snowfall was 41 per cent, and the seasonal precipitation 67 per cent of normal."

Cities depending on supplies from natural stream flows may well be concerned over the possibility of being entirely without a supply. The chemical composition of the water may be completely changed by an abnormal reduction in the flow, particularly if the natural flow is mixed at any point with industrial or municipal wastes. The possibility that there will be extremely severe conditions this season makes it imperative that engineers should keep these facts in mind and should be on the lookout for the appearance of any unusual characteristic in the water supplies under their supervision. Before the drought is over, emergency measures may be necessary at many points, due to the sudden appearance of taste and odor problems or to an intolerable increase in mineral constituents that are not ordinarily objectionable.

The Central Valley Project of California

An Approved Method of Combating Aridity and Salt-Water Encroachment and of Improving Navigation

By Edward Hyatt

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Irrigation in California was begun in a general way about fifty years ago. The area of the irrigated land grew rapidly until it has become more than five million acres. Roughly, three million acres lie in the Central Valley of the state, traversed by the Sacramento River from the north and the San Joaquin River from the south. Vast storage reservoirs and canal systems have been built to make the rainfall, which occurs in the winter months, available for summer use. But still overdrafts on ground-water supplies are required for both agricultural and domestic use, so that additional storage of winter flood waters is needed to provide proper irrigation of the area now under cultivation.

After a complete inventory of the water resources of the state, a plan has been developed. Already the Metropolitan Water District of Southern California has the Colorado River Aqueduct under construction to serve that section. The Central Valley Project contemplates a large reservoir of 3,000,000 acre-ft capacity at Kennett on the upper Sacramento River. This reservoir will provide flood protection in the winter, stop salt-water encroachment in the lower reaches of the river, and assure year-round navigation. By a system of canals, conduits, and pumping plants, excess water from the reservoir will be made available to the orchard and farm lands of the San Joaquin Valley. This diversion from the Sacramento River will be augmented by water from the San Joaquin River stored behind a 250-ft dam at Friant. It is estimated that the gross cost of $170,000,000 for the Central Valley Project, when reduced by certain anticipated Federal appropriations, can be defrayed by the sale of water and hydro-electric power. This description of the project is an abstract of the paper presented by Mr. Hyatt before a joint session of the Irrigation and Power Divisions of the Society, July 12, 1934, at the Vancouver Convention.

It is unnecessary to stress the value of water in the western half of the United States. It is recognized as all-important in the semi-arid sections. For continued growth, and in some places even for the maintenance of established centers of population, water development projects are absolutely necessary.

The Central Valley Project of California proposes the regulation, stabilization, and redistribution of the water supplies of a large part of the state. Agriculture in California is mainly dependent on irrigation, which was started in a substantial way about 1885. Since then it has increased rapidly, until now there are about 5,000,000 acres watered, or one-fourth of the total amount of irrigated land in the United States. This development, which started by diversion of the summer flow of streams to neighboring lands, has broadened to include large storage works, long conveyance canals, development of large areas distant from the source of the water, and extensive use of ground water. Coincident with the increase in irrigation, large-scale municipal and hydro-electric power projects have been built, and there are now more irrigated lands and more hydro-electric developments in California than in any other state.

Yet there is a limit to natural water supplies, even when they are regulated by storage. About 1920 it became apparent in California that not only was the growth of the state being restricted by lack of water, but that many areas had been overdeveloped so that wholesale abandonment of certain sections would inevitably result unless more water were obtained. This was partly the result of years of subnormal rainfall and failure of run-off, but more particularly of the overdrafts on ground-water sources that were thought to be inexhaustible.

Twelve-Year Study of Water Resources

This situation led to practically a state-wide demand for relief. In 1921 the state undertook the formulation

Extensive Areas Devoted to Orange Crops in Southern San Joaquin Valley
Overdraft from Natural Water Sources Has Already Caused Abandonment of Orchards Where Supply Has Failed

of a comprehensive program to cure existing deficiencies and provide for the regulation and utilization of available supplies for the future. This study, which has proceeded continuously to date, has culminated in the Central Valley Project. An exhaustive investigation has been made and more than 25 reports issued. Practically all the organizations in the state, both public and private, that were able to contribute to it have done so. The plan was evolved by engineers who had the benefit of excellent legal and financial advice. Also, many national agencies, particularly the U. S. War Department and the U. S. Bureau of Reclamation, participated to a major extent in the plan. To date, over a period of about 12 years, approximately $2,000,000 has been spent in the preparation of this water plan and project.

As usual, the major share of the work has fallen to the engineers. The first step was the making of a complete inventory of the water and land resources of the state, which was carried through during the first two or three years of the study. This was an immense technical task. It involved the determination of the water supply and its regulation in hundreds of watersheds, a complete inventory and classification of all irrigable lands, and an estimate of water requirements for those lands. The magnitude of the work necessitated the creation of new methods of engineering analysis to make possible mass production.

When the results became available, it was found that there was approximately enough water in California, considering the state as a whole, to overcome the existing crisis and to provide for reasonable future needs. However, there were two great obstacles: first, the water that nature makes available comes largely during the winter months, whereas it is needed mainly in the summer; and, second, the bulk of the water is to be found in the northern part of the state, whereas the main need, both for the present and the future, is in the southern part.

Fig. 1. Central Valley Project of California—Map of Proposed Construction

Comprehensive Plan Developed

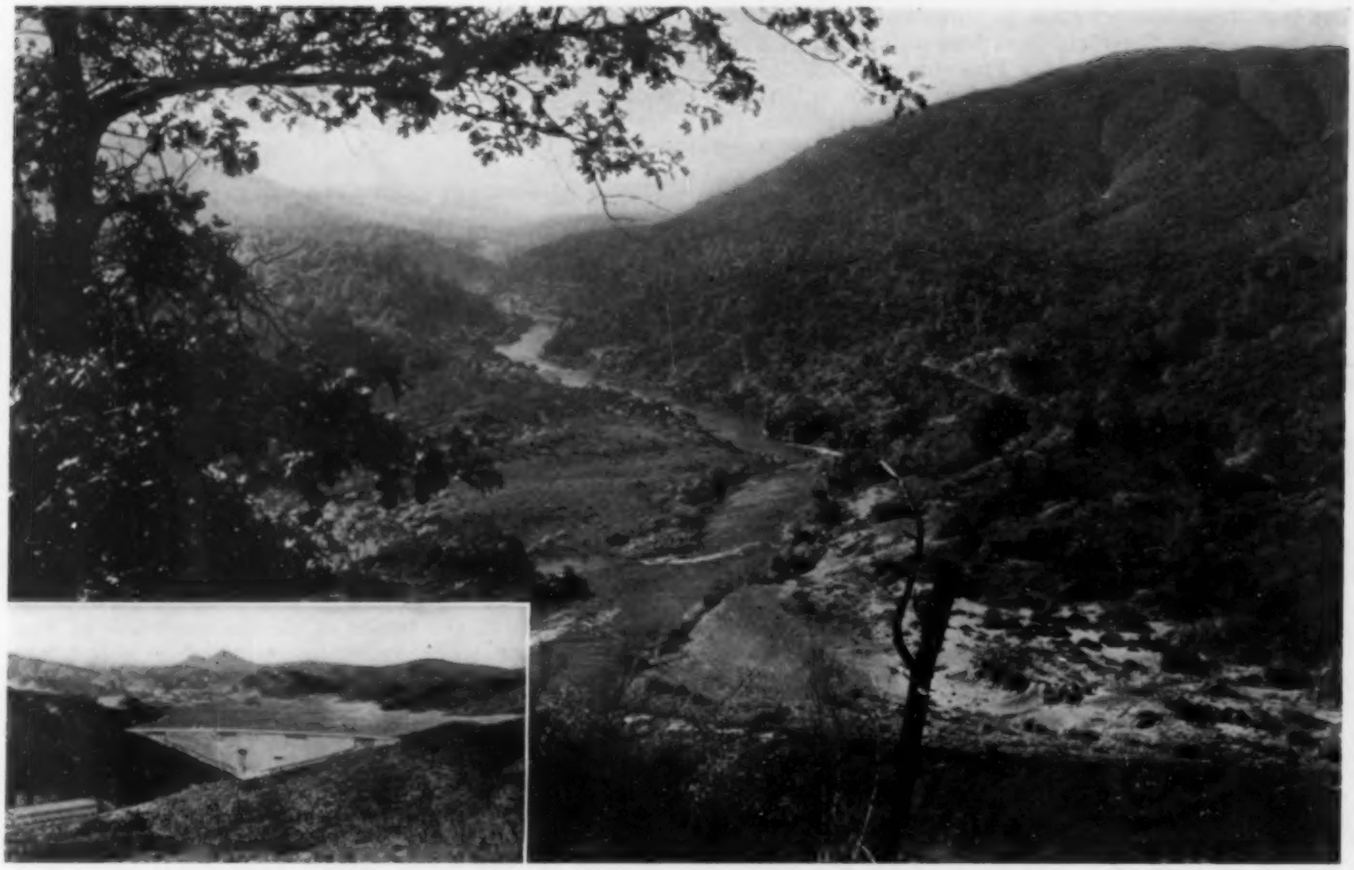
On the basis of the very complete data at hand, two economic plans were then formulated to overcome these physical obstacles. They concerned the construction of regulating reservoirs and the conveyance of water to the place of need. The final engineering plan was presented to the California Legislature in 1931 in a report entitled "Bulletin No. 25 of the State Engineer." Although this plan encompasses the entire state, Southern California, through the Metropolitan Water District, has proceeded independently with the unit recommended for that section, namely, the Colorado River Aqueduct. The Central Valley Project affects the Sacramento and San Joaquin basins, which contain about two-thirds of the irrigable and irrigated lands of the state.

As shown on the map, Fig. 1, the Central Valley of California lies in the basins of the Sacramento and San Joaquin rivers. The valley floor, which is about 500 miles long and 40 miles wide, has a population of approximately 900,000 and includes 3,000,000 acres of irrigated land. Its hydro-electric development of 1,600,000 hp is more than four-fifths of the total amount of such power developed in the state. The metropolitan area around San Francisco Bay, with a population of 1,200,000, depends on it for domestic water. An accurate classification of the land shows that there are over 9,000,000 acres of irrigable land in the valley, and that the power possibilities are for an additional 5,000,000 hp. It is an agricultural and commercial hinterland supporting the metropolitan centers of Los Angeles and San Francisco, which must share in its prosperity or decadence. Thus a total population of more than 4,500,000 people is directly affected.

It is in this valley, and particularly in its southern half, that the most critical water shortages have arisen and that there will be a reversion of large areas to desert conditions unless more water can be obtained. The emergency is most acute in two sections. In the southern part of the San Joaquin Valley five counties are affected, and 400,000 acres of highly developed lands, now irrigated and supporting a high type of American civilization, have inadequate water. It is estimated that half this acreage, with a direct capital value of $50,000,000, must be abandoned within the next few years unless the water shortage is remedied. Overdevelopment of ground-water supplies has been largely responsible for the trouble, since there are thousands of individual pumping plants in the area. Local supplies are insufficient, and the additional water needed can be obtained only from the surplus in the Sacramento basin hundreds of miles away.

Salt-Water Encroachment to be Prevented

The other major problem centers in the delta formed by the confluence of the Sac-



LOOKING DOWNSTREAM TOWARD THE SITE OF THE KENNETT DAM; IN INSERT, ARTIST'S CONCEPTION OF 240-FT STRUCTURE

ramento and San Joaquin rivers, which join near Stockton and flow into upper San Francisco Bay. Here there is an area of about a half-million acres of extremely rich agricultural lands, largely peat, reclaimed during the past 40 years by the construction of levees, which produce crops valued at $30,000,000 a year. Water for irrigation is obtained from the Sacramento and San Joaquin rivers and the many side channels and by-passes in the area.

As the result of a variety of causes, but mainly of the diversion of the rivers above for irrigation, the flow has diminished to a point where it is insufficient to hold back the advancing salt water from San Francisco Bay, which is brought in twice daily by the tides. A small section of the delta has already been ruined by the salt water, and a large part of it is seriously menaced. In the dry year of 1931 damage to crops alone in this area was estimated at $1,300,000, and the situation will be bad this present year. Abandonment of land on a large scale will result here also if no remedy is found.

Lying below the delta on the south shore of Suisun Bay is a very attractive commercial area now occupied by industries whose annual output of manufactured products is valued at more than $100,000,000. These industries, too, have been seriously damaged by the encroachment of salt water, and the area has stopped growing. Navigation on the Sacramento River, one of the important inland waterways of the country, has likewise been seriously injured. In dry years the river is not navigable above Sacramento during the summer months. These are the main water problems. There are many others, such as problems of flood control, domestic use, and hydraulic mining.

As laid out, the Central Valley Project solves all these difficulties in a practical manner at the least possible cost. It provides for all present known uses of water and lays the foundation for future extension of the system when necessary and justified. One of the cardinal principles of the plan is that only surplus water in excess of all possible future needs shall be drawn from one basin to the other. The project provides for the various types of uses in such a way as to secure maximum utility for each with the minimum of interference.

KENNETT RESERVOIR TO PROVIDE LARGE STORAGE

Previous studies have demonstrated that large-capacity reservoirs situated in the foothills, the dividing line between the mountains and the valley floor, can be coordinately operated to serve a wide variety of uses with but small interference between types. In the Central Valley Project the large reservoir which it is planned to build in the foothills serves to re-regulate all upstream storage. The plan provides that upstream water development for all purposes, including hydro-electric power, irrigation, and mining, shall proceed unrestricted under public or private initiative, and that after such use the water shall be re-regulated and used again by means of this reservoir. If the reservoir itself has a large capacity, it can be used to a considerable extent for the control of floods by withholding a predetermined amount of storage space available for that purpose. If the structure is properly designed, this will not interfere materially with the value of the water for power because when the storage space is withheld, flows larger than average are available for power generation. Water will be released from the reservoir in accordance with the schedule that will best meet all needs.

In the case of the Kennett Reservoir, which will have a capacity of 3,000,000 acre-ft, 500,000 acre-ft of space will be withheld during the winter for flood control,

INDUSTRIAL AREAS ALONG SUISUN BAY, CALIFORNIA

and the stored water will be released during periods of low flow to meet the needs of domestic water supply, irrigation, navigation, and control of salinity. This reservoir, to be located in the foothills at the upper end of the Sacramento Valley, will be the main storage structure of the Central Valley Project. The height of the dam will be 420 ft, and it is planned to build a 275,000-kva hydro-electric plant immediately below it. In the coordination of these various uses there is a surprisingly small degree of interference, since the demands for navigation, irrigation, and salinity control are at a maximum when the power load is greatest.

The physical units of the project can best be described by reference to the map, Fig. 1. The Kennett Reservoir is located on the Sacramento River, where there is a surplus of water. The water released, after passing through the power house, will flow down the natural channel of the river to the delta, stabilizing and increasing navigation facilities for a distance of 200 miles, eliminating the existing shortage of water for irrigation along the river, and providing sufficient fresh water in the delta area to prevent the encroachment of salt water. It will also eliminate large-scale litigation between the delta region and the upper Sacramento Valley, which threatens to ruin one or the other.

To provide for the industries along Suisun Bay, a canal will divert fresh water from the delta by means of pumping plants and deliver it to the industrial section. This will solve the water problems of the Sacramento Valley and the delta without the construction of the proposed salt-water barrier—a dam across Carquinez Straits—which would be expensive to the point of being uneconomic, as well as a serious impediment to navigation. Sufficient water to relieve the emergencies in the southern San Joaquin Valley will reach the delta region by means of gravity, but the problem of how best to conduct it there, a distance of 200 or 300 miles, was a serious one. The economic solution reached was the construction of the San Joaquin Pumping System and of the Friant Dam on the San Joaquin River.

CONDUCTING WATER TO THE SAN JOAQUIN VALLEY

Water to the amount of 3,000 cu ft per sec will be diverted from the delta near Stockton by means of large pumping plants and transported southward, using the channel of the San Joaquin River as a conduit. A series of dams and pumping plants will deliver this water to Mendota on the San Joaquin River, a distance of 150 miles from Stockton, at an elevation of 160 ft. It is believed that the numerous problems involved, such as those of foundation, drainage, and passage of flood waters, have been successfully met in the design. It is not proposed to lift this water further upstream than Mendota, but to deliver it at that point to existing canals, which now divert the flow of the San Joaquin River in a larger amount than 3,000 cu ft per sec. In exchange the same quantity of water as is now routed to these canals will be diverted from Friant Dam at an elevation of 467 ft, and taken to the Upper San Joaquin Valley. The result of this exchange of Sacramento River water for San Joaquin River water will be a saving in pumping lift of 300 ft. It is believed that the proposal is sound from both the physical and the economic standpoints.

Friant Dam will be 250 ft high and will have a storage capacity of 400,000 acre-ft. It will regulate the flow of the San Joaquin, or rather re-regulate it, since the Southern California Edison Company and the San Joaquin Light and Power Corporation have extensive storage and hydro-electric power developments upstream.

Some small amount of surplus water now existing in the San Joaquin River will be made available by the dam, but the main supply will be that coming indirectly from the Sacramento River. An average of 1,600,000 acre-ft will be available at the Friant Dam. This supply will be conveyed a distance of 157 miles southward by the Friant Kern Canal and for 35 miles northward by the Madera Canal for distribution to irrigated lands. The proposed project is not intended for the development of new lands or for the material extension of irrigation but is designed to furnish sufficient water to maintain the established population and development of large areas already occupied.

Although power development is in a sense a by-product, it is important in that it is expected to produce one-half of the revenue for the project; thus a 220,000-v transmission line from the Kennett power house to the load center of the territory in the delta, a distance of 200 miles, is included.

CELERY PRODUCTION ON SACRAMENTO–SAN JOAQUIN DELTA LANDS Irrigated from the Lower Reaches of the Two Rivers, Where Salt Water Is Encroaching

An integral part and a most important feature of the engineering plan is the utilization of the ground-water reservoirs in the upper San Joaquin Valley. Here there are 20,000,000 acre-ft of underground storage space available, if utilized by pumping. At the present time, there is an installed well and pump capacity in excess of 20,000 cu ft per sec, or over 1,200,000 acre-ft per month, if operated continuously. Where suitable underground storage is available and a proper control of draft and replenishment is exercised, it is a most flexible and economical means of conserving and utilizing water over a period of years.

NINE MILLION ACRES OF FERTILE LAND

It is obvious that the project involves vast distances, huge engineering works, and great expense, and that it has tremendous potentialities. Designed at this time to meet only emergencies of so dire a nature that they involve not only the state but also the nation, it is the foundation of an even greater system for the future, since additional storage units in their economic order can be brought in as necessary.

When this project is built there is no reason why the Central Valley, with its 9,000,000 acres of good land and its advantages of climate, should not become an inland empire, supporting a population much greater than at present. Its prosperity will have an immediate commercial effect on the adjoining metropolitan centers and states. If the plan is not carried out, abandonment of large areas will result in a capital loss of possibly $100,000,000, with a consequent effect on the rest of the state and on the nation.

The cost estimates of actual construction are as follows: Kennett Dam, including relocation of the Southern Pacific Railroad, the afterbay dam, and two power houses, $84,000,000; transmission line, $14,000,000; industrial conduit, $2,500,000; San Joaquin pumping system, $20,000,000; Friant Dam, $14,000,000; canals leading from Friant Reservoir, $30,000,000. The total, including miscellaneous items, is between $165,000,000 and $170,000,000, depending on methods of financing.

Revenues to defray the carrying charges will come from two sources, the sale of water and the sale of electric power. Exhaustive investigations have been made to determine the need of water and a reasonable price for it, and the value of the power and the length of time required for its absorption into the general market. The anticipated revenues from these two direct sources alone are insufficient to meet the costs of the project on the basis of state financing. There is, however, a direct and justified Federal interest in the project, which, if converted into actual financial participation, will make it economically feasible.

In this connection the U. S. War Department, through the Corps of Engineers, has reviewed the entire project in detail over the last three or four years, and its last report, "Rivers and Harbors Committee Document No. 35," dated April 6, 1934, recommends a national contribution to the Kennett Dam of $12,000,000 by reason of its benefits in navigation, flood control, and salinity control. This appropriation was authorized by the Rivers and Harbors Committee on April 13, 1934.

WATER PROJECT AUTHORITY CREATED

As regards organization, the California Legislature in its 1933 session passed the Central Valley Project Act, creating the Water Project Authority of the State of California to construct and operate the project and to defray the costs by the sale of revenue bonds. The Authority is empowered to execute contracts for the sale of water and power and to compel compliance with such contracts when executed. The act was submitted to a referendum vote of the people at a general state election held on December 19, 1933, and was ratified by a substantial majority.

In September 1933, the late Governor Rolph of California filed an application with the Federal Emergency Administration of Public Works for the construction of the Central Valley Project, but because the act was held up by the referendum, the application was not transmitted to Washington. In January 1934, it was resubmitted by the Water Project Authority and has since been under investigation by the Public Works Administration. The application asks that the project be Federal to the extent of the $12,000,000 recommended by the Chief of Engineers and authorized by the Rivers and Harbors Committee, and to the extent of a grant of 30 per cent of the cost of labor and materials on the remainder, amounting to $37,000,000. It also asks that the Public Works Administration accept revenue bonds to the amount of $116,000,000 for the rest of the financing. With this method of financing, a favorable financial showing results.

It is evident that the Central Valley Project is one of merit and of national concern. It is no longer a question of whether it will be carried out, because it must be built to prevent a major tragedy in a large area. It is rather a question of how soon and under what auspices it will be constructed.

Municipal Refuse Problems and Procedures

A Survey of Methods of Collection and Disposal in 53 Pacific Coast Cities

By C. G. Gillespie, M. Am. Soc. C.E.
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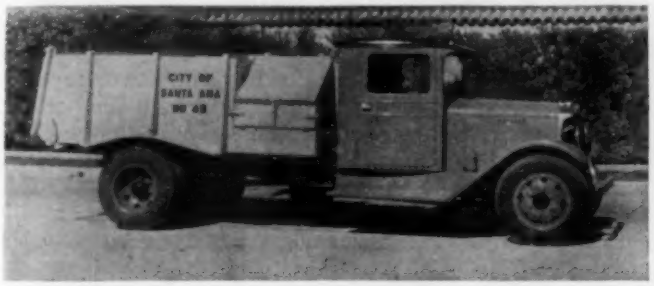
Data concerning methods of collection and disposal of municipal refuse in 53 cities of over 10,000 population in British Columbia, Washington, Oregon, and California cannot fail to be of interest to the sanitary engineer. The material on which this study is based was obtained partly by personal visits but chiefly through letters and questionnaires. The interpretation of these data is in conformity with the prevailing use of terms in each of the cities investigated, these being usually defined by local ordinances. The various factors which determine the procedures of the individual cities are so complex that a careful analysis of them is practically impossible. However, the authors discuss a number of the more important basic principles, classify in simple terms the methods of collection and disposal, and point out trends of practice in this important field of municipal endeavor. The original paper, of which this article is an abstract, was presented before the session of the Sanitary Engineering Division on July 12, 1934, during the Society's Annual Convention at Vancouver, B.C.

The problems involved in keeping a city and adjacent countryside clean of municipal refuse at minimum expense are necessarily varied and are influenced by population and population density; the habits of the people; the form of government; the ownership of the utilities, whether governmental or private; and considerations of topography, roads, and



Garbage Truck Lined with Monel Metal

the nature of the countryside. Procedures should therefore conform to circumstances and needs. Nevertheless, it seems that there has been regrettably little of the engineer's analytical approach to the problems presented. One of the salutary signs detected is a growing tendency of city officials to compare notes with one another and to adopt fewer and better procedures. All aim at cheaper and more complete removal of municipal refuse and at more creditable methods of final disposal.

Methods of Financing

Payment of the charges for municipal disposal is made in many ways, all of which fall into three general groups: (1) taxation, that is, from the general fund; (2) service charges collected by the municipality; and (3) service charges collected by the private contractor. In the 52 cities reporting on this subject, 19, mainly in Southern California, finance collection and disposal by taxation. In 7, collection of the service charge is by the city, in some cases by the water department or other publicly owned utility on the department's bill. In 26, the private scavenger does his own collecting. Of course it does not necessarily follow that there is municipal refuse collection in the cities depending on taxation or having municipal collection of the service charges. They may contract with a private scavenger for that service, retaining in their own hands the collection of the moneys.

The strong argument for the taxation method is that it comes nearest to assuring universal service, and only on such a basis is the cost of removal the lowest. The theory on which this practice is based is that refuse removal is a proper and necessary governmental function, required for the protection of the health and safety of the community. Like sewage removal, education, and the protection of health and property in general, this service should be free to all regardless of their ability to pay. In the matter of refuse collection and even removal of sewage, however, this theory has given way in many cities to the necessity for a more dependable source of support for the service in the face of an increasing drain on tax moneys. The recent trend has been away from the taxation method, toward schemes of financing dependent on collection from the actual users of the service.

Collection and disposal of refuse are still generally done by private waste scavengers; 26 of the cities reported that method. The scavenger is his own bill collector, either with or without regulation of the amount of the charge by the city. Variations from this simple method are found in various places. Most places set up a basis for special service and may or may not prescribe the rates to be charged. Some cities bill the householder on his water, light, or gas bill.

Ordinance Provisions

Copies of ordinances were furnished by about half the cities heard from. The general form of ordinance reported covered the keeping, collection, and disposal of municipal refuse. The following subjects were handled in greater or less detail:

1. Definition of terms used, particularly swill, garbage, combustible and non-combustible rubbish, tree trimmings, and ashes.
2. Authority to make contracts for collection and disposal of refuse.
3. Containers, usually water-tight metallic cans of specified shape and size, with tight-fitting lids, in sufficient number to hold all materials accumulating between collections.

REFUSE DISPOSAL IN SANITARY FILLS AT BERKELEY, CALIF.
Garbage Dumped Between Fences and Covered with Dirt

4. Location of container, which should be convenient for collection, usually in backyard, in alley, or at curb, there placed by householder on day set for collection.
5. Segregation of various materials as defined in the ordinance.
6. Collection at intervals of from one day to one week for garbage and mixed refuse, and up to two months for non-combustible refuse.
7. Vehicles for collection required to have metal or metallic-lined bodies with metal or canvas covers and to display the name of the city and the collecting agency.
8. Permits for operating collection business if done by a private agency, and license fees.
9. Control of collection and disposal vested in health officer, city engineer, or some other official.
10. Rates of charges, if any, classified in accordance with type of service needed.
11. Penalties for violation of the ordinance.

In many ordinances the disposal method is outlined and the location of the disposal area given. Some prohibit disposal on public or private property, while others allow certain forms of private disposal. A few ordinances expressly prohibit the individual from transporting his own refuse; a few allow it if a permit is obtained; and others allow it without restriction. Several ordinances contain sections prohibiting interference with refuse cans by private parties.

PRIVATE COLLECTION OF REFUSE

Of the 52 cities reporting on method of collection, 31 have private scavenger service under regulation by contracts varying from a day-to-day period to as long as 10 years. Some replies indicate that a 5-year period does not justify the contractor in obtaining adequate or proper equipment. In 7 of these 31 places, the city keeps the collection of the bills in its own hands.

The financial provisions of the contracts are variable. In some cases the rate is based on tonnage collected, in some on a flat rate, and in some on a percentage of the receipts. Often separate contracts are made for the collection of swill, and in several instances separate collection of rubbish is reported. Many cities allow individuals to haul rubbish to the disposal site. Some allow dumping free of charge, and others make a charge for the cost of handling at the dump. In towns having private scavenger service, the argument in favor of allowing individuals to haul their own refuse to the disposal site, with or without charge, is that it removes the temptation to dump on vacant lots or roadsides and so results in a cleaner city.

SEGREGATION OF WASTE

More or less segregation of the different wastes is practiced in nearly every city reporting. In 21, swill is segregated, but only from restaurants and hotels. Cities feeding garbage to hogs usually have but two classes—garbage and rubbish. Still others go a step further and separate rubbish into combustible and non-combustible. Los Angeles has all four segregations: swill, household and market garbage, combustible rubbish, and non-combustible rubbish.

The question of segregation is closedly related to the method of disposal and is largely dependent on the habits of the people in a given community. The comment of a city official in San Francisco at a public meeting was that if a candidate wanted to be sure of defeat, he had only to mention that he was in favor of requiring the housewife to separate garbage and refuse. Many cities report that householders take easily to wrapping the garbage, as it keeps the can dry and clean, prevents rust, and prolongs the life of the receptacle. Hog feeders object to paper in the garbage, and one city engineer reported, "Hogs do not eat paper."

FREQUENCY AND PLACE OF COLLECTION

Variations in the frequency of collection of garbage and refuse, as reported, are from once a day to once a month. If the so-called "clean-up weeks" are included, one might extend the period to once a year. The common schedule is daily collection in the business district and weekly collection in the residential area. Cities disposing of garbage to hogs usually collect at least twice weekly, since fresh garbage makes the better feed.

An important element in the cost of collection of refuse appears to be the point from which collection is made, as there appear to be factors of economy other than the mere difference in travel distance from the curb to the backyard. For example, with curb collection, the scavenger can use a tub to advantage and collect from two

Emergency Landing Field at Berkeley, Calif.
Built on Finished Sanitary Fill Along the Bay Shore

or more premises before dumping into the truck. On the other hand, the sight of garbage cans and receptacles lining the curbs and front yards is objectionable to those who are particular about the appearance of their city. Backyard collections are reported from 28 cities, and curb collections from 12, whereas 3 report both. The majority of cities disposing of garbage by hog feeding, as is the practice in Southern California, have curb collections. Costs in cities having backyard collection are noticeably higher than in similar cities having curb collection.

New Types of Trucks Developed

In many cities the men in charge of the work have given a great deal of thought to the type of truck used. Improvements from time to time have resulted in a gradual lowering of the height of bodies with a view to saving man power in loading and unloading. For the sake of economy, the larger cities appear to be adopting trucks of larger capacity, until now 12 and 14-cu yd trucks are not uncommon.

A new 12-cu yd truck designed by the Berkeley Garbage Department has a low body, the highest point being only 60 in. above the ground. Drop boards on the sides allow it to be partly filled with still lower lifts. Unloading is done by a transverse diaphragm, which when not in use stands upright behind the cab. A pair of chains extend to the tailboard. The truck is unloaded by attaching these chains to cables, which in turn are fastened to a "dead man" at the dump, or to a tractor. The diaphragm simply slides the contents out the back with a minimum of scattering of papers and refuse.

The City Engineer of Santa Ana has designed a unique 3-ton garbage truck which has an enclosed steel body, of the dump type, lined on the inside with monel metal. The truck is loaded through side doors at the front end. At intervals, a hoist tilts the body backward, causing the material to fill the rear part. Loading is then resumed until the truck is full. The tailboard is practically water-tight.

Trucks for handling mixed refuse, combustible refuse, and non-combustible refuse are made in a great variety of sizes and shapes. In general, they are emptied by backward tilting, by the use of a diaphragm, or by hand. In some cities, divided or compartment trucks are used so as to keep garbage and rubbish separate for disposal.

In some cases reported the haul is to a loading depot, but in most cases it is to the dump site. The shortest was at Olympia, Wash., where swill is hauled only one-half mile, partly for hog feeding and partly for feeding at a fox farm.

The longest haul reported was at San José, Calif., more than 30 miles for swill and 11 miles for mixed refuse. Two cities have long hauls from loading depots to disposal sites. At Los Angeles swill and garbage are transported by a train of gondola cars about 50 miles to the hog ranch of the Fontana Farms Corporation in San Bernardino County. At Oakland, Calif., mixed refuse is transported over 40 miles by boat to dumping grounds off the the Golden Gate, 25 miles from the nearest shore. The state law in California, passed in 1911, forbids dumping of garbage, refuse, or swill in any navigable water of the state within 20 miles of any coast line in the state.

Thirty-four cities reported the weights of mixed refuse collected. Most of these were estimates, as only a few places had accurate records. The average weight was 1.13 tons daily per 1,000 population, or 824 lb per capita per year. Eleven cities reported on the weight of garbage alone, the average being 0.39 tons daily per 1,000 population and 284 lb per capita per year. Ten cities reported on refuse only, averages being 0.58 ton daily per 1,000 population and 424 lb per capita per year. Only three cities reported on swill, the average being 0.092 tons daily per 1,000 population, or 67 lb per capita per year.

Disposal Methods

The most common methods of disposal reported are the combination of feeding swill or swill and garbage to hogs, with disposal of other refuse by dumping on land or burning on dumps. A survey by the Bureau of Sanitary Inspections of the California State Department of Public Health in 1930 showed that of 242 cities in the state, 192 had private collection and disposal, and 48 had municipal collection and disposal. In 162 cases, wet garbage was used for hog feed, and the other refuse was deposited in designated dumps; in 68 cases all the refuse was deposited on designated dumps; in 7 cases incinerators were provided; and in 3 cases refuse was disposed of at sea.

Smaller cities generally dispose of municipal refuse by promiscuous dumping. As the community grows and civic pride is awakened, improvements are made, first by

confining the dumping to restricted areas, later by the use of deep fills, with plank runways for trucks, and sometimes by the feeding of hogs on the dump and burning the more combustible materials. These simpler methods are nearly always unsatisfactory on account of odor and smoke nuisances, flies, rats, and other rodents. They always create an eyesore, particularly if the dump is within sight of any public road. Eventually the public demands improved disposal methods.

LOADING GARBAGE BOAT FOR OCEAN DISPOSAL, OAKLAND, CALIF.

In logical sequence the next step in improvement is the development of the "sanitary fill" or fill-and-cover method. Occasionally material is burned before being covered, but the general practice is to cover the material each day, at least on top, and at times on the face. The depth of fill material is from 5 to 25 ft, and the cover, from 6 in. to 2 ft or more. If this method is carefully controlled, care being taken to keep a small exposed face and to spread and smooth the finished surface, it may be employed to reclaim low-lying areas for such uses as parks, recreation fields, golf courses, and airports. Areas so reclaimed are generally not suited to become building sites.

The Commissioner of Public Works at Fresno, Calif., after a careful survey of methods used in other cities throughout the state, reported that the fill-and-cover method "properly handled is as good as incineration, costs about one-third, and further does not require a large outlay of money." He proposes the use of the method on flat land, excavating 3 ft deep to get material for cover, dumping 8 ft deep, using 2 ft of top cover, and covering the side slopes at least twice a week. The dump location at Fresno is at least a half mile from the nearest farmhouse.

INCINERATION

Municipal incinerators appear to have been more widely publicized than any other disposal method, and general opinion seems to favor them from the viewpoint of sanitation. However, experience indicates dissatisfaction with incineration, chiefly because of high cost, inadequate capacity, and resulting unsatisfactory performance. More specifically, the objections to it are that unburned or partly burned refuse must be dumped, with resulting odor nuisance and fly and rat menace. An incinerator, to operate successfully, should be used 24 hr a day, at a fairly uniform temperature and charging rate. This condition is seldom attained in practice because collections are generally made during the daytime, and the great bulk of material arrives within a short period of time. The inevitable result is either an accumulation of unburned material on the charging floor or the overloading of furnaces, or both.

Four cities reported disposal of all or part of their mixed refuse by incineration. In Fresno, Calif., private collection and disposal will be supplanted by municipal service in October 1934, and the incineration method will be abandoned for the fill-and-cover. Five cities reported disposal of combustible refuse by incineration. In all of them an attempt is made to have materials segregated. Vancouver incinerates 8 tons out of a total of 214 tons of refuse handled daily; Portland, 75 tons out of 237; and Los Angeles, 100 tons out of 780.

DUMPING AT SEA

One of the oldest methods of waste disposal is dumping in bodies of water. The return of floating solids to the shore has been the cause of numerous complaints, and in California has resulted in a state law prohibiting the discharge or dumping of garbage into navigable waters or the Pacific Ocean within 20 miles of the shore. Many years ago Oakland, Calif., disposed of garbage by dumping from barges at sea, but the method was abandoned because in rough weather the trip across the bar at Golden Gate could not be made safely with the boat then used. Garbage dumped inside the Gate floated back to near-by shores. The ship and crew of 9 men were lost at sea in 1916, and the fill-and-cover method was used on the harbor front until 1925, when disposal at sea was again adopted.

Victoria, B. C., also dumps mixed refuse at sea, although the more combustible material is disposed of in a burner. Bellingham, Wash., reported disposal of mixed refuse three miles from shore in Bellingham Bay, an arm of Puget Sound. Port Angeles, Wash., reported disposal of mixed refuse to the straits of Juan de Fuca where the tidal sweep is reported to carry it away.

HOG FEEDING A FAVORED METHOD

Conservation of food values in garbage was widely publicized during the World War, and the method is widely used, particularly for swill from restaurants and hotels. Most of the cities in Southern California dispose of garbage as well as swill by the hog-feeding method. One report states that no other method is used by the 44 municipalities in Los Angeles County. Important features of successful hog-feeding systems are delivery of garbage in a fresh condition, feeding on concrete floors, and the daily clean-up and prompt disposal of waste and manure. Cities using this method have collections at least twice weekly. Los Angeles County has an ordinance requiring a permit for hog farm locations and making feeding on concrete floors obligatory. Disposal of wastes and manure has been the most troublesome feature, yet of the 37 farms operating in Los Angeles County in 1930, complaints were registered against only two. In one of these cases carelessness was the cause, as the owner was giving up the business.

Hog feeding is a private enterprise in all cases reported. Wide variations are found in financing. In some instances the general franchise or contract includes garbage and swill with all refuse; in some, a special contract is awarded for garbage collection only; in some, the contractor buys garbage at a flat rate per ton; and in some, the rate is based on the price of hogs, and no payment is made when the price falls below a stated amount. Still others provide further that the city will pay for garbage removal if the price drops below another stated amount. During periods of prosperity, some cities have received considerable sums for their garbage contracts, but in recent years receipts have dwindled. In some cases it has been necessary to pay the hog feeder

to continue in business. Since swill has a higher food value than household garbage, most cities receive an income from this source, although in some cases the hotels and restaurants are paid directly by the hog-feeding company for the materials collected.

WORLD'S LARGEST HOG FARM

Hog feeding of garbage and swill from Los Angeles by the Fontana Farms Corporation in San Bernardino is of such interest that a brief statement of the methods used is pertinent. From 400 to 600 tons daily are brought to the farm in a train of steel gondola cars. Garbage is fed to 46,000 hogs within a fenced area of 220 acres. The farm is divided into four units: the brooder unit, including farrowing pens and small pig pens; the weaning unit; the feeder unit; and finally, the fattening unit. The garbage is classified and fed in the following way. That from restaurants and hotels, comprising 25 per cent of the material received, is fed to finishing hogs, and that from households, making up the remaining 75 per cent, is fed to brooders. Garbage for the feeder and fattening units is fed from cars, that for other units, from trucks and wagons.

All feeding is done on concrete floors. Those in the feeder and fattening units are cleaned daily by a mechanical floor cleaner, and those in the other units, by hand. Railroad tracks are on concreted runways and are washed daily, the drainage being used for irrigation. Since this has been found too concentrated for crops, in the future it will be mixed with other water. Farrowing pens are cleaned daily and are washed and disinfected between broods at intervals of from three to four weeks. Earth pens are cleaned about once a month by raking the refuse into piles and then shoveling it into trucks. The manure from these pens contains a large amount of dirt and sand and makes a low-grade fertilizer, which is not sold but used on the company's property.

PROBLEM OF DISPOSAL OF WASTE FROM HOG FARMS

The most perplexing problem is the disposal of waste and manure from the concrete feeding floors. At first this was composted, but the odors were terrific, fly breeding was very troublesome, and the material composted very slowly, requiring large storage capacity. The present method is to spread it in a layer on concrete platforms constructed for the purpose. There it is turned by plow and treated with lime or gypsum to assist in drying and odor control. After it has been dried, it is piled; glass and bones are picked out from a belt; iron is magnetically removed; and finally it is ground and screened through a 1-in. by $^3/_4$-in. screen. It is then sold by the ton as commercial fertilizer.

Five thousand tons of low-grade fertilizer are produced each year, and 20,000 tons of the commercial fertilizer. The latter has a moisture content of 5 or 10 per cent and a nitrogen content of 2 to 2.5 per cent. The company owns the adjoining land on all sides. The nearest neighbor is a quarter of a mile distant. Under present conditions, the pork produced averages 44.55 lb per ton of garbage. Before the depression, when more food was wasted as garbage, as high as 65 to 70 lb of pork per ton were produced. This is said to be the largest hog farm in the world.


Unloading Gondola Car to Concrete Floor of Feeding Pens


1,500 Tons of Fertilizer Sold to Orange Growers

Los Angeles Garbage Fed to 46,000 Hogs by Fontana Farms Company

DISPOSAL COSTS SUMMARIZED

Less information is available on costs of disposal than on any other phase of the problem. In most reports received it is not clearly stated whether such items as interest, depreciation, replacements, and supervision are included. Reported costs of collection and disposal vary from \$1.40 per ton for garbage only, at Glendale, to \$7.85 per ton for mixed refuse at San José, Calif. In general, the cost for collection is far greater than that for disposal. In a survey of municipal garbage disposal by the Los Angeles County Live Stock Department in 1930, the average cost of garbage collection in 62 cities throughout the United States was found to be \$2.94 per ton. No average was figured in the present survey because the data are not comparable.

The lowest cost for disposal was reported by Sacramento, Calif., where comprehensive cost data on the fill-and-cover method give a total of 18.9 cents per ton. At Berkeley, with the same method, the cost is reported as 31.5 cents per ton. Disposal at sea for Victoria, B.C., costs about 30 cents per ton. At Oakland, Calif., ocean disposal was let by contract at 65 cents per ton, so that the cost was probably somewhat less than this amount. Costs for incineration are reported by Vancouver, B.C., as \$1.38 per ton; by Spokane, Wash., as about 90 cents per ton; and by Los Angeles, Calif., as \$1.46 per ton. The latter city also reports capital charges of \$1.38 per ton, giving a gross cost of \$2.84 per ton.

In conclusion, it is desired gratefully to acknowledge the cooperation of the city engineers and other officials who so kindly furnished the data presented here. Most helpful cooperation in the preparation of this report has been given by Charles Gilman Hyde, M. Am. Soc. C.E.

ENGINEERS' NOTEBOOK

From everyday experience engineers gather a store of knowledge on which they depend for growth as individuals and as a profession. This department, designed to contain practical or ingenious suggestions from engineers both young and old, should prove helpful in the solution of many troublesome problems.

Moment of Inertia of Corrugated Sheets

By H. B. Blodgett, Assoc. M. Am. Soc. C.E.
Assistant Professor of Civil Engineering, South Dakota State College, Brookings, S.D.

Corrugated sheets are frequently used as beams. If the common theory of flexure is assumed to apply, the flexural stresses may be computed by the common flexure formula, $f = \frac{Mc}{I}$, in which f is the unit flexural stress at extreme fiber; M, the bending moment; c, the distance from neutral axis to extreme fiber; and I, the moment of inertia. The evaluation of the moment of inertia is the most troublesome of any of the four factors involved.

Before the moment of inertia of any section can be expressed, it is necessary to know the geometrical shape of that section. There is probably no simple geometrical form that will exactly represent the true section of the corrugated sheets in common use, although various investigators have made certain assumptions concerning these forms. It has been assumed that the cross section of a corrugated sheet is composed of cycloidal arcs, parabolic arcs, circular arcs, straight lines, and certain combinations of these. It has also been assumed that the arcs are sine waves and catenaries. Very little reference to the properties of these sections as assumed is to be found in engineering literature. I suggest the following four relations, by means of which the moment of inertia of a corrugated sheet may be determined:

1. If the arcs of the corrugations are assumed to be cycloidal, the moment of inertia may be expressed as,

$$I = C_1 b d^2 t \quad \ldots\ldots\ldots [1]$$

where b = width of the corrugated sheet (not the developed width); d = depth of corrugation; t = thickness of the sheet; e = pitch of corrugations, that is, distance from ridge to ridge; $k = \frac{e}{d}$

$$C_1 = \frac{2}{15}\left[1 + \frac{8}{3}\left(\frac{1}{k}\right)^2\right] \quad \ldots\ldots [2]$$

Equation 1 was first proposed by Professor Rankine in 1868 and has been used in a modified form ever since. It is slightly approximate in derivation.

2. Assuming the arcs of the corrugations to be parabolic, the moment of inertia may be expressed as

$$I = C_2 b d^2 t \quad \ldots\ldots\ldots [3]$$

where
$$C_2 = \frac{2}{105}\left(6 + \sqrt{1 + \frac{16}{k^2}}\right) \quad \ldots [4]$$

and b, d, t, and k have the same definitions as before. Equation 3 is slightly approximate in derivation.

3. If the arcs of the corrugation are circular, as in Fig. 1, the moment of inertia may be expressed as

$$I = C_3 b t^3 + C_4 b d^2 t \quad \ldots\ldots [5]$$

in which
$$C_3 = \frac{(6\alpha - \sin 2\alpha)}{48 \sin \alpha} \quad \ldots\ldots [6]$$

$$C_4 = \frac{(4\alpha + 2\alpha \cos 2\alpha - 3 \sin 2\alpha)}{16 \sin \alpha \operatorname{vers}^2 \alpha} \quad \ldots [7]$$

$$\alpha = \tan^{-1}\left(\frac{4k}{k^2 - 4}\right) \quad \ldots\ldots\ldots [8]$$

and b, d, t, and k have the same definitions as before. Equation 5 is rigorous in derivation and will give an exact evaluation of the moment of inertia, if the arcs are truly circular.

4. If the cross section of the sheet is composed of tangents and circular arcs, as in Fig. 2, the moment of inertia may be expressed as

$$I = C_5 b t^3 + C_6 b d^2 t \quad \ldots\ldots [9]$$

where
$$C_5 = \frac{(6\alpha + 3 \sin 2\alpha - 8 \sin \alpha) q + 4 \sin \alpha}{12k} \quad . [10]$$

$$C_6 = \left[\left(6\alpha + \sin 2\alpha - 8 \sin \alpha - 4\,\frac{\tan^3 \alpha \sin^2 \alpha}{3}\right) q^3 + (4 \sin \alpha + k \tan^3 \alpha \sin \alpha - 4\alpha)\, q^2 + \left(\alpha - \frac{k^2 \tan^3 \alpha}{4}\right) q + \frac{k^3 \tan^2 \alpha}{48 \cos}\right] \div k \quad \ldots\ldots [11]$$

$$q = \frac{(k \tan \alpha - 2)}{4 \operatorname{exsec} \alpha} \quad \ldots\ldots [12]$$

α = the acute angle which the tangent makes with the neutral axis, as indicated in Fig. 2

and b, d, t, and k are as previously defined.

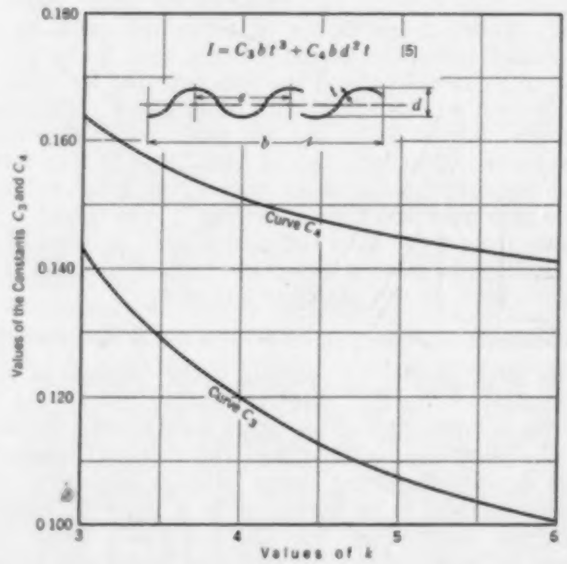


Fig. 1. Moment of Inertia with Assumed Circular Arcs

Equation 9 is rigorous in derivation and will give an exact evaluation of the moment of inertia if the section is actually as assumed.

Equations 2 and 4 may be evaluated with little numerical effort. Equations 6, 7, 8, 10, 11, and 12 are not so easily calculated, and the use of charts is the easiest way to apply Equations 5 and 9. Such charts have been drawn and are reproduced in Figs. 1 and 2.

Given the moment of inertia as evaluated by any one of these relations, the section modulus, S, may be expressed as

$$S = \frac{2I}{(d + t)} \quad . \; . \; . \; . \; . \; . \; . \; [13]$$

An approximate section modulus, S_1, may be expressed by the relation,

$$S_1 = \frac{2I}{d} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; [14]$$

which was done in the original Rankine formula. For comparatively thin sheets and deep corrugations the use

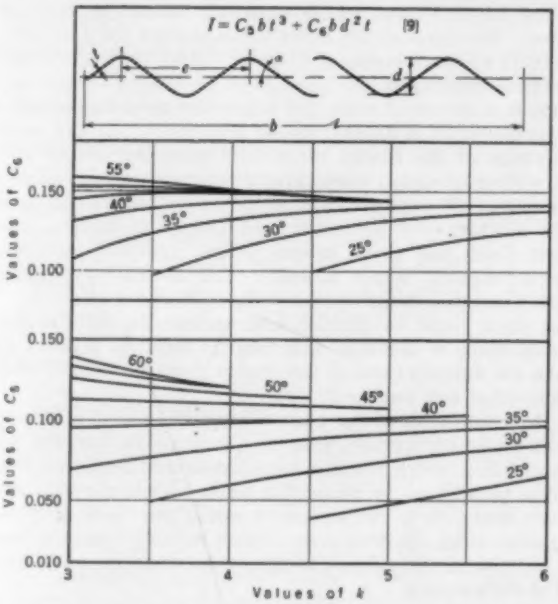


Fig. 2. Moment of Inertia When Section Is Composed of Tangents and Circular Arcs

of Equation 14 may be all right, but Equation 13 seems preferable.

For any particular section, the moments of inertia as computed by Equations 1, 3, 5, and 9 will not vary greatly. Since the assumption of tangents and circular arcs is probably the most nearly representative of the shape of the corrugated sheets in common use at the present time, the use of Equation 9 is recommended.

Assume a corrugated sheet, whose section is composed of circular arcs, with a width, b, of 12 in.; depth of corrugation, d, of $^9/_{16}$ in.; and a pitch, e, of 3 in.

$$k = \frac{e}{d} = 3 \times \frac{16}{9} = 5.33$$

Enter the chart, Fig. 1, with the value of k as an argument, and read from the C_3 curve, 0.105, and from the C_4 curve, 0.143. Substituting these values in Equation 5,

$$I = 1.260\, t^3 + 0.542\, t \text{ (in.}^4\text{)}$$

When the thickness of the metal in inches is substituted, the numerical value of I results. If Fig. 1 were not available, C_3 must be computed from Equation 6, and C_4 from Equation 7.

If the section of the sheet being considered is assumed to consist of arcs and tangents, the chart shown in Fig. 2 will aid in the solution. Assume a sheet 12 in. wide, having corrugations 0.5 in. deep and 2.67 in. apart, and the acute angle between the tangent and the neutral axis of the sheet to be 30 deg.

$$k = \frac{e}{d} = 2.67 \times 2 = 5.33$$

Enter the lower part of Fig. 2 with 5.33 as an argument and read the value of C_5 on the 30-deg curve, 0.078. In the upper half of the chart find C_6 to be 0.134. Substituting these values in Equation 9,

$$I = 0.936\, t^3 + 0.402\, t \text{ (in.}^4\text{)}$$

Without the chart the values of C_5 and C_6 must be calculated from Equations 10, 11, and 12.

In connection with my study of this problem, acknowledgment is made of the interest and suggestions of Robins Fleming, of the American Bridge Company, and E. C. Hartmann, Jun. Am. Soc. C.E., of the Aluminum Company of America.

Our Readers Say—

In Comment on Papers, Society Affairs, and Related Professional Interests

Field Experience with Border Strip Irrigation

Dear Sir: In his article on "A Formula for Border Strip Irrigation" in the April issue, Professor Goodrich reaches some conclusions that do not agree with field experience. In the last paragraph he says that, ". . . for any given length of border strip, the product of the time in hours required to cover the strip and the given irrigation head, measured in cubic feet per second, is a constant when the proper values of K and C are known." Field trials demonstrate that the time required is proportionately less with larger heads. This result is to be expected as the longer time required by the smaller head permits greater infiltration. If the time required to cover the strip were inversely proportional to the size of head, the total quantity of water applied would be the same, regardless of the head and the corresponding time required. Since more water is absorbed during the longer time required for the smaller head, less water would be left on the surface from the smaller head. This also is to be expected and tends to mask the effect of the greater infiltration for short runs and short periods of time. In the data quoted by Professor Goodrich the head per foot width of strip is 0.6 times as great on tract A as on tract B. At shorter distances the time required for the advance of the stream on tract B is about 0.6 times as great as on tract A. But at 2,000 ft the time is only 0.5 times as great, and at 2,300 ft it is even less.

Professor Goodrich suggests that the value of his constant C may become less than unity. With a value of less than unity for C, the curves of his Fig. 1 would become convex to the axis of

length of border, thus indicating a more rapid advance of the stream as time passed. This is certainly contrary to usual experience and seems illogical.

The conclusion that, with values of C less than unity, there is a theoretical limit to the length of strip that may be irrigated seems to be based on an error caused by equating the value of $\frac{dt}{dL}$ to zero rather than that of $\frac{dL}{dt}$. Further confusion is caused by the conclusion in the author's Equation 5 that "p may be taken equal to the rate of change of y with respect to the time." This would make the rate of infiltration zero when the depth is constant.

Curves having the rational formula given by Orson W. Israelsen, M. Am. Soc. C.E., in his book on *Irrigation Principles and Practices*, will fit the data quoted by Professor Goodrich as well as or better than the curves in Professor Goodrich's Fig. 1, derived from the empirical equation, as is shown in the accompanying Fig. 1. Values of y and p were computed from two points (marked m and n in Fig. 1) from each set of data. These values follow:

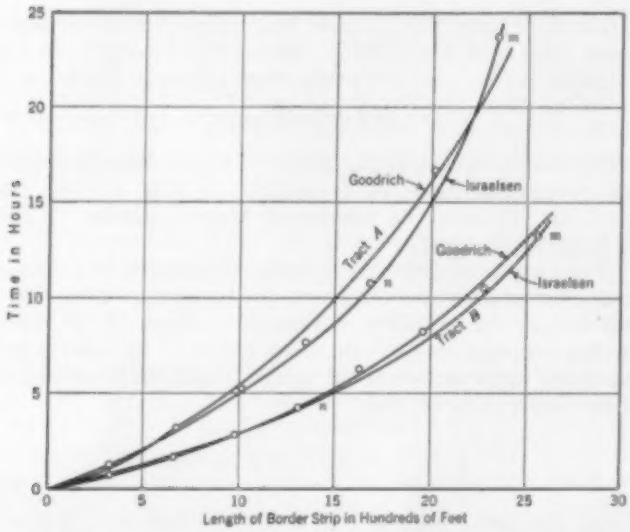


FIG. 1. COMPARISON OF FORMULAS WITH EXPERIMENTAL DATA

TRACT	Y IN.	p IN. PER HR
A	7.9	0.765
B	8.3	1.05

The curves marked Israelsen in the accompanying Fig. 1 were plotted by using these values together with the known values of q and B. It is possible that a closer fit could have been secured by adjusting the values of p and y.

In spite of the fact that a very fair approximation is secured when p is taken as a constant, it is probable that Dr. Israelsen's conclusion that the rate of infiltration normally decreases with the length of time water is held on the soil, is correct. There is considerable experimental evidence that this is true.

The factor L has been omitted accidentally from the last term of Professor Goodrich's Equation 3.

M. R. LEWIS, M. Am. Soc. C.E.
Irrigation Engineer, Bureau of Agricultural Engineering, U. S. Department of Agriculture, Oregon State Agricultural College

Corvallis, Ore.
August 5, 1934

An International Forest Park

TO THE EDITOR: At the meeting of the Metropolitan Section on May 16, 1934, following the reading of a most interesting paper on "Meteorology" by Dr. A. K. Lobeck, of Columbia University, I made a suggestion that may be of interest to the general Society membership, as it concerns a desirable national development.

Anyone from the East, on going to St. Louis for the first time or, in fact, to any part of the Mississippi Valley, must have marveled at the sudden extremes of temperature. This is undoubtedly due to the utter lack of any "wind break" from the Gulf of Mexico to the northern part of the Canadian prairies.

For years I tried to evolve some practical scheme for overcoming this serious handicap. Finally it seemed to me that an International Park Forest was the right solution. So in 1913 I submitted a plan to the governments of the United States and Canada, suggesting that each buy a strip of land 10 miles wide, making a total width of 20 miles, to extend from Lake Superior to the Pacific Ocean, a distance of about 1,500 miles. I suggested that they make of this area an International Forest Park, a home for wild animals, birds, and fish.

The advantages of a "wind break" such as this would form must be apparent to all. It would surely benefit the climate and thus greatly enhance the value of the land from the Gulf of Mexico to Saskatoon, Saskatchewan, and Edmonton, Alberta. By proper management the area could be made not only self-supporting, but also profitable, through the sale of timber, furs, animals, and fish.

This park should start from the shores of Lake Superior, the surface of which is 600 ft above the sea level, where the land abruptly rises to an elevation of from 1,000 to 1,500 ft for a distance of about 350 miles. Most of this area is included in the wild and beautiful Lake of the Woods district and has a very large number of rivers and lakes in both Minnesota and Manitoba. Then the level drops slightly for 50 or 60 miles, while crossing the Red River Valley, which separates Minnesota from North Dakota. For the next 200 miles the land rises from an elevation of 1,000 ft to an elevation of 2,000 ft. Here the park would still be in the prairie region.

Then in a stretch of some 550 miles, the ground gradually rises from an elevation of 2,000 ft to one of 4,000 ft. At this point the main range of the Rocky Mountains suddenly towers into the skies, with magnificent snow-capped peaks, which can be seen for many miles. Thence the park would extend across the backbone of the Rockies, the Kootenay and Columbia valleys, and the Selkirk, Gold, and Coast ranges to the Straits of San Juan de Fuca—a majestic forest indeed! The maximum elevation in British Columbia would be about 13,000 ft above sea level.

The park could be divided into vast areas, suitable for the different kinds of animals; and tourists could be given a chance to view the animals through iron fences, from the tops of viaducts, or from other safe positions.

If the boulevards of the park were made free to all, enormous crowds would continually visit the "greatest park in the world," thus affording much revenue to railroads and hotels all over the country, as well as to steamship lines. Also, the sale of furs, animals, and fish to the sightseers would pay both governments a big interest on the investment, apart entirely from the incalculable benefits of the project to the entire country, both east and west of the Rockies.

T. KENNARD THOMSON, M. Am. Soc. C.E.
Consulting Engineer

New York, N.Y.
July 16, 1934

Another Three-Hinged Arch Bridge

TO THE EDITOR: In the April issue of CIVIL ENGINEERING an article by Leon Blog entitled "Temporary Hinges in an Arch Bridge" contains the following statement, "So far as is known, this was the first reinforced concrete arch bridge to be erected by the three-hinged method in the United States." Subsequent contributions to the publication mention other reinforced concrete bridges, designed in 1929 and later, in which hinges were also used.

In order to add to the available data on this subject, I wish to call attention to the Hampden County Memorial Bridge across the Connecticut River at Springfield, Mass., designed by my firm, and constructed in 1920–1922. This bridge contains seven arch-rib spans varying in length from 117 ft 6 in. to 188 ft. All of these were constructed as three-hinged arches, the center hinge being enclosed after the ribs were constructed to obtain the increased rigidity furnished by a two-hinged structure under live loads.

C. M. SPOFFORD, M. Am. Soc. C.E.
Fay, Spofford and Thorndike
Consulting Engineers

Boston, Mass.
August 10, 1934

SOCIETY AFFAIRS

Official and Semi-Official

First Ballot for Official Nominees Reported

Procedure for the annual election of Society officers, as provided by the Constitution, calls for a "First Ballot" for Official Nominees to fill those positions of Vice-President and Director that are to become vacant the following January. Thereafter a Second Ballot is issued, and on the basis of this, in turn, a final ballot is canvassed the following January. In the meantime the official nomination for President is made by the Nominating Committee, usually in October.

This year the First Ballot was canvassed as required, on August 1, and its results are given in the following official report:

New York, N.Y.
August 1, 1934

To the Secretary
American Society of Civil Engineers:

The Tellers appointed to canvass the First Ballot for Official Nominees report as follows:

Total number of ballots received		1,193
Deduct:		
Ballots from members in arrears of dues	148	
Ballots without signature	7	
Ballots from members who have died since voting	1	
Total withheld from canvass		156
Ballots canvassed		1,037

For Vice-President, Zone II

D. H. Sawyer	228
Frank L. Nicholson	144
Scattering	41
Void	0
Blank	9
Total	422

For Vice-President, Zone III

Henry E. Riggs	286
Ineligible candidate	23
Scattering	87
Void	1
Blank	50
Total	447

For Director, District 3

C. Arthur Poole	40
Edward H. Sargent	22
Ineligible candidate	10
Scattering	14
Void	0
Blank	0
Total	86

For Director, District 5

Herman Stabler	64
Charles W. Kutz	50
Edwin F. Wendt	39
Scattering	12
Void	0
Blank	11
Total	176

For Director, District 7

James L. Ferebee	99
Scattering	18
Void	0
Blank	3
Total	120

For Director, District 8

Charles B. Burdick	47
Frank T. Sheets	7
Ineligible candidate	7
Scattering	15
Void	0
Blank	5
Total	81

For Director, District 9

H. S. Morse	81
Ineligible candidate	7
Scattering	3
Void	0
Blank	4
Total	95

For Director, District 12

Ivan C. Crawford	57
Ross K. Tiffany	14
Ineligible candidate	5
Scattering	6
Void	0
Blank	0
Total	82

For Director, District 16

Theodore A. Leisen	66
Thomas R. Agg	6
Ineligible candidate	10
Scattering	5
Void	1
Blank	3
Total	91

Respectfully submitted,

J. J. Hennebique, *Chairman*

James A. Darling — Bertram J. Ahearn
Odd Albert — John J. Cope
Charles M. Madden — Charles Carswell
Charles D. Thomas — B. S. Voorhees
A. W. Buel

Tellers

Manual No. 8 Is Distributed

All members in good standing have recently received copies of the latest Society Manual, the eighth in the series. Its general subject is "Engineering and Contracting Procedure for Foundations," and within this subject are included procedure for "Bridge Foundations," "Building Foundations," and "Responsibilities of the Contracting Parties."

This is the first issue of a Manual in almost three years. While a number of excellent manuscripts have been made available in the interim, Society finances have not warranted the necessary expenditure. During the current year, however, the Board of Di-

rection feels that extraordinary efforts should be made to publish a number of Manuals now in hand.

Manual No. 8 is the first of three to be issued, it is hoped, during the current year. Because of its wide applicability and utility to all members, it has been distributed in full edition. The Manual has been formulated by a committee of the Construction Division headed by Alonzo J. Hammond, Past-President Am. Soc. C.E. Great credit is due to his committee for their valuable work under two subcommittees, that on bridges, headed by Carlton S. Proctor, M. Am. Soc. C.E., and that on buildings, headed by L. R. Viterbo, M. Am. Soc. C.E.

History of Engineering Code

MANY QUESTIONS have been raised by members as to the preliminaries and history of the Society's connection with the Code of Fair Practice for the Engineering Division. A number of these questions have been answered in a letter from the Secretary to the President of the Society, under date of June 28, 1934. All sorts of historical data, matters of procedure, individuals and organizations affected, and reasons for particular details are fully covered. The information given is attested by various documents.

By instruction of the Board of Direction at its Vancouver meeting, mimeographed copies of this report are to be made available to members upon request. Inquiries should be addressed to the Secretary at Headquarters.

Activities of Society Research Committees

IN SPITE of the handicaps of limited finances, the research committees sponsored by the Society, or by it jointly with other organizations, are making notable progress. In reporting to the Board of Direction at its meeting in Vancouver, Thaddeus Merriman, M. Am. Soc. C.E., Chairman of the Committee on Research, noted the following developments and prospects, as of July 9, 1934:

For the Committee on Concrete and Reinforced Concrete Arches, Chairman Clyde T. Morris, M. Am. Soc. C.E., reports that:

"The committee held a meeting in New York on November 11, 1933, at which the formulation of a Final Report of the committee was discussed at some length. It is the hope of the committee that the final report may be in shape for presentation at the Annual Meeting in 1935."

. . . .

For the Committee on Earths and Foundations, Chairman Lazarus White, M. Am. Soc. C.E., reported that the committee is continuing its work generally along the lines laid out in previous years.

"At Columbia University under the direction of the School of Engineering Professor Berkey is adapting the centrifuge so as to give, in combination with photo-elastic cells, a new method of determining the stresses created by a mass of earth impinging against a bakelite model of a retaining wall or other structure, such as the lining of a tunnel. Variations in the speed of rotation give variations in the weight of gravity of the mass. Stresses set up in the restraining model may be observed directly by eye or camera and computed by well-established photo-elastic methods. The apparatus is one of great ingenuity and the method of great promise. The committee expects to report on the results of the method in the near future. This work is being done in cooperation with Engineering Foundation, whose aid financially and otherwise is greatly appreciated.

"In Europe, Professor Terzaghi is continuing his work of observing and recording settlements of existing structures and is conducting his research work at the Technische Hochschule in Vienna.

"Professor Krynine is continuing his experimental work at Yale University, and the committee is being aided by Professor Gilboy at the Massachusetts Institute of Technology.

"The committee is conducting experiments on models of dams built of sand on sand foundations, and expects to report on this work. These models are representative of cofferdams now being constructed on the Mississippi River."

. . . .

For the Committee on Stresses in Railroad Track (a joint committee of the Society and the American Railway Engineering Association), Chairman A. N. Talbot, Hon. M. Am. Soc. C.E., reports that:

"The Sixth Progress Report was sent to Secretary Seabury in manuscript form in November 1933. The same report was published by the American Railway Engineering Association as Bulletin No. 358 in August 1933. It contains 244 printed pages, 97 figures, and 35 tables.

"Since completing this report the work of the staff has continued on tests on rail joints in track, the design of joint bars, and the investigation of locomotive counterbalancing as it affects rail stresses and track depressions.

"Tests were also made on the special stretch of concrete road bed of the Pere Marquette Railroad.

"A staff of four men and a stenographer are employed regularly on the investigational work.

"The funds for the investigation are being supplied by the American Railway Association."

. . . .

The recently established Committee on Hydraulic Research, of which J. C. Stevens, M. Am. Soc. C.E., is Chairman, reported progress in organization along the lines laid down by President Eddy when the committee was established. H. D. Vogel, Assoc. M. Am. Soc. C.E., Secretary of this committee, is stationed at the U. S. Waterways Experiment Station at Vicksburg, Miss., and the results of the work at that station on the field investigation of model results will be available to the committee.

. . . .

Gerard H. Matthes, M. Am. Soc. C.E., Chairman of the Committee on Flood Protection Data, which was established by the Board of Direction in January last, reported progress and stated:

"It is expected that the committee's main endeavor at first will be directed toward deciding which of the many methods of analyzing flood data and analyzing frequency studies now in vogue are most practical and reliable rather than to devise new methods."

. . . .

For the Committee on Cement, Chairman Thaddeus Merriman, M. Am. Soc. C.E., reported progress. This committee has kept in close touch with the situation through Committee C 1 of the American Society for Testing Materials, and the time is not far distant when it will be able to report on the very substantial progress that has been made in the art and technique of cement manufacture. Particular examples are the recent specifications for "low test" cement as indicated by the requirements for the Pine Canyon, the Hoover, and the Norris Dam. Requirements for "alkali resistance" cements are exemplified by the specifications of the Fort Peck project and those of the Tennessee Valley Authority. The monumental investigations of the Bureau of Reclamation as to all phases of cement behavior have been a most potent factor leading toward the development of portland cement.

. . . .

For the Committee on Dams, your committee reports progress. H. de B. Parsons, M. Am. Soc. C.E., of this committee is collecting data on uplift pressure and is experimenting at the Rensselaer Polytechnic Institute on the lateral pressures of sand. D. C. Henny, M. Am. Soc. C.E., has written a most important paper on "Stresses in Gravity Dams," which has evoked much new discussion, including that of S. H. Woodard, M. Am. Soc. C.E., of the committee on an advanced concept of stress.

CONCLUSION

Under present conditions nearly all the Research Committees are compelled to function through the individual members. The lack of appropriations precludes them from meeting, and it is therefore a great pleasure to be able to report substantial progress in spite of adverse conditions.

Determining Acceptability of Papers for "Proceedings"

Notes Prepared by the Editorial Staff by Direction of the Committee on Publications

That among members there is great unfamiliarity with the methods adopted by the Society for handling its manuscripts for Proceedings is apparent from the many inquiries continually being received at Headquarters. It may help in the general understanding and appreciation of the extensive problems involved and their solution, if some of these questions and their answers are repeated.

Who has charge of Society publications? Fundamentally the Board of Direction controls this as well as every other activity. On behalf of the Board a standing committee, designated the Committee on Publications, is given full power. Ordinary decisions of the committee are final, but in extraordinary cases appeal is made to the Board itself. The committee is further supplemented by the Secretary of the Society and a full-time member of the Society's staff, who acts jointly as the secretary of the committee and as the Manager of Publications. In the latter capacity, he has general supervision of the details of editing, printing, and purchasing publication supplies. The entire editorial and publication staff consists of eleven persons, exclusive of the advertising department. Of these eleven, four are technically trained engineers, members of the Society.

Who may submit manuscripts? There is no restriction on the authorship of Society papers. By far the larger part are provided by members, because of their interest in professional activities and as a matter of duty to the Society. The technical content and not the authorship determines the acceptability of a paper. As between two papers of equal merit, of which only one could be accepted for economic reasons, doubtless the manuscript written by a member would have preference over the other by a non-member.

How are manuscripts obtained? Most manuscripts for Proceedings are submitted directly by authors, addressed to the Secretary of the Society or to the Committee on Publications. These general papers are not solicited by any authorized officer, nor is any financial recompense given. Repeatedly the committee has found it necessary to emphasize that no person in the Society either officially or unofficially is authorized to pledge acceptance of a paper.

Subjects for Society and Division meetings are solicited by those in charge of these meetings. Such papers are also eligible to be considered for Proceedings after abstracts have been published in Civil Engineering. For this eventual use they are recommended and transmitted through the executive committees of the Divisions.

In what form are manuscripts required? In general, three complete copies of manuscripts are needed, one of which should be an original on substantial paper. This copy is the one later used for editing, if the manuscript is accepted. Text must be typewritten, double spaced. Blueprints of text are not acceptable. Drawings and diagrams should be specially prepared, if necessary; working drawings are seldom satisfactory. Photographs have to be of generous size and more than average distinctness; snapshots are seldom satisfactory. These provisions all have the definite purpose of expediting consideration by the committee or use by the editors. A number of additional details are given in a special pamphlet available on request. Before the paper is further studied, the author is requested to assure the committee that his manuscript is in large measure original with him and that it has not been published or distributed under other auspices. Technical information "readily found elsewhere" is not acceptable.

Who reviews papers? In its technical study of the various subjects, the Committee on Publications depends largely on opinions secured from selected reviewers. For this purpose it maintains a list of several hundred men, almost exclusively members of the Society in some grade. Obviously the leaders of the profession predominate, although Juniors are also eligible. For example, young instructors of exceptional ability or former Freeman Fund scholars are frequently consulted. The character of engineering ability represented by this list is remarkable and constitutes a guarantee of the very best opinion obtainable.

The file of expert reviewers is continually being revised. Whenever information is secured indicating the advisability of so doing, names are added. The list is subdivided into over twenty categories, according to the special qualifications of the individuals. These classifications in turn include a wide variation of interest, so that not only the man's specialized field but his particular training or interest in that field is taken into consideration.

How are reviewers selected? The committee considers that the proper persons to report on a paper should be:

1. An engineer particularly qualified by technical training and experience to judge the subject matter of the paper.
2. A person with a nice sense of discrimination who, from his wide acquaintance with the field, has extraordinary ability to judge relative values and the applications of principles.
3. One who is in sympathy with the high ideals of the Society in publishing only the choicest material submitted.
4. A man of high ethical standards who will treat the questions as confidential and who will give an unbiased decision.

To aid in attaining these objectives those reviewers are chosen who are best able to fill these specifications. In general, this means that no associate of the author will be selected and probably no one resident in his community. Furthermore, any personal relationships that may be known are taken into consideration so that the reviews may be free from bias either for or against the author and the paper.

Seldom do reviewers decline the request of the committee. In order, however, not to impose on their generosity, a list is maintained of reviewers and their reports so that the work may be distributed as fairly as possible. In almost every case the reviewers are further distributed geographically in order to avoid any local consensus.

How many reviewers are required for each paper? The general rule is to secure three reports on every paper for Proceedings, This is sufficient if any unanimity of opinion is indicated. If not, the inquiries are extended as far as may seem reasonable. It is not infrequent that the committee eventually secures six or eight or even more reports.

How are independence of review and anonymity secured? Fairness to the author and the reviewer has led the committee to conduct all its business on the basis of anonymity between the author and the reviewer. The authorship or other identifying marks are removed from the manuscripts before they are sent out. Frequently the utmost precautions do not prove sufficient, but ordinarily the reviewer may have, at best, only suspicions as to the source of the material. Furthermore, while the confidential opinions are frequently used in the revision of papers, the author is not advised as to the source of these views. The purpose of these precautions is to make it as easy as possible for the expert to be perfectly frank and perfectly fair. There has never been cause for complaint that the committee has abused this confidence.

What determines acceptability? The selection of suitable papers for Proceedings comprises one of the major duties of the Committee on Publications. Such papers are considered at regular meetings of the committee, which are held at intervals of two to three months. More frequent meetings are impracticable on account of the wide distribution of committee members and the resulting inconvenience of meeting and because of the expense to the Society. This is one of the most active standing committees of the Board, and hence methods of lightening its labors are desirable. Furthermore, the normal latitude in the schedule of publications permits this interval between meetings without detriment to the publications or to the authors. In emergency, when it is imperative that a decision be reached in advance of a regular meeting, committee members are canvassed by letter.

Acceptance of papers is made in the order of their excellence. At any meeting the total number accepted is naturally limited within the current ability of the Society to publish according to the existing budget. Obviously this means that only a fraction of the total manuscripts are finally utilized. During recent years, with their impaired budgets, this fraction has been relatively small because of the following combination of factors: (1) a relatively large obligation had been accepted during more prosperous years and accordingly a generous number of papers were on hand; (2) the resulting delay until the surplus was absorbed was accordingly

increased; and (3) the reduced budgets made the normal number of acceptances smaller than previously. As a result of these conditions, the acceptances for PROCEEDINGS during the years 1931 and 1932 were unusually low, about 18 per cent of the total received; whereas the rate since that time has been about 39 per cent. Over the years 1930 to date the rate has been about 30 per cent.

It does not follow that, because a paper is well conceived and well prepared, there is assurance of its acceptability. Only the best of the good papers can survive the competition and these have to meet the further test of diversification of current subject matter for the publication taken as a whole. Obviously also, the committee's decisions, like any other judgments subject to human elements, are not infallible. It is the general experience of the committee, however, that the procedure adopted actually accomplishes the purposes it is calculated to effect, and that by and large the judgment is verified in the sequel.

What disposition is made of rejected papers? When circumstances warrant, the paper may be placed in a deferred file for reconsideration when circumstances favor. This applies particularly to a paper that is obviously worthy but which for temporary reasons cannot be used immediately. Another class of papers requires revision according to the specific recommendations of reviewers. These papers are returned to the authors with the request that they cooperate in effecting immediate changes.

A frequent difficulty is the size of manuscripts. Large subjects require corresponding space. The Committee on Publications, on the other hand, conceives it to be in the best interest of the profession that the space devoted to any one paper be limited. For the benefit of readers a concise treatment is demanded. In the interest of the entire membership a number of relatively briefer papers is far superior to a single longer one costing the same amount. Furthermore, such shorter papers may cover diversified subjects and thereby serve a wider audience.

A paper which has positive or partial value, but which for other reasons is not acceptable, is frequently placed in the Engineering Societies Library. A proper item in CIVIL ENGINEERING records this fact and gives a brief abstract of the contents. All the foregoing dispositions are subject to the approval and cooperation of the authors.

There remains finally the fairly large class of papers that cannot be utilized. These are returned, with regret and appreciation, to the authors.

How long is a paper in the hands of the committee? Obviously these details take considerable time, depending largely on the speed of review, the excellence of the manuscript, and the proximity of a committee meeting. In extreme cases acceptances have been effected within about a month after submission. The ordinary interval is apt to be from five to six months. In exceptional cases, as when only one transcript is available; or when reviews are difficult to obtain and slow coming in; or, as often happens, when the reports suggest that extensive rearrangement is advisable, the period of study may extend over one or two years.

Publication in PROCEEDINGS follows at the earliest possible date. At present, this interval is from three to five months after acceptance. The committee considers that a lapse of six months should be the maximum desirable. Excellence of material and its presentation rather than speed are considered paramount.

Are discussions treated like papers? Such exhaustive scrutiny is neither necessary nor desirable as applied to discussions for PROCEEDINGS. The committee, however, has set up definite principles for the guidance of the editors. Usually these indicate prompt classification, which if favorable assumes immediate publication of the discussion in the first available number. Marginal or controversial cases go to the committee itself for decision.

Are papers for "Civil Engineering" subject to the same rules? On account of its character, CIVIL ENGINEERING must have a more flexible program than PROCEEDINGS. Frequently papers submitted for PROCEEDINGS are adjusted, on recommendation of the committee, and in collaboration with the author, to the requirements of CIVIL ENGINEERING. More frequently, papers do not require the intricate study and report here explained in detail.

What is the present prospect for papers? In both publications a normal supply of manuscripts is on hand, and only reasonable intervals before publication are to be expected. Those who anticipate submitting papers to the Society should request a copy of the leaflet giving "General Information on Society Publications and Preparation of Manuscripts for PROCEEDINGS." Practical suggestions there given facilitate publication both for the author and the Society. The Committee on Publications is always pleased to receive manuscripts for possible use either in PROCEEDINGS or CIVIL ENGINEERING. It undertakes to give a careful and impartial study of each case. The committee believes its procedure guarantees that, within human limitations, its decisions will be reflected in the maximum of benefit to the Society and to the profession at large.

Becoming a Member of the Society

AN ORDINARY visitor at Headquarters is apt to be astounded at the amount and diversity of work necessary in handling the multitudinous office details. Obviously this necessitates a staff specially trained for the various activities of a world-wide technical organization.

One of the many never-ending tasks carried on by the staff is the handling of details connected with applications for membership in the Society. An engineer makes application to join the Society, either in person or by mail. When his application form is received at the office, his name is listed for publication in PROCEEDINGS. This constitutes a notice to each member, whose duty it is to notify the Board of Direction of any reason he may have why the application should not be favorably considered. Also, letters are written from Headquarters to all the applicant's references and to his employers. Then too, local committees aid the Board in making a more extended examination into the record of the applicant. Board members themselves, with the aid of the records prepared by the membership department of the Headquarters staff, devote hours to digesting all the reports and making recommendations. Action is not taken by the Board in official session until every detail of the history of the applicant has been investigated, verified, and checked. All these data are made a part of the official files of the Society.

When a favorable vote has been taken by the Board, the new member is notified, and as soon as he qualifies, current publications are sent to him. He is given an opportunity to order a badge and a certificate of membership and may use the title appropriate to his grade of membership. The accounting department begins a new account in his name for all future financial transactions. When a member is transferred from one grade to a higher one, a similar procedure is required.

During the year 1933, which for obvious reasons was not the most active of recent years, the new applications handled numbered 715, and the new members who completed their qualifications totaled 534. So far in 1934 there has been a relative gain in both these categories. Needless to say, the careful scrutiny given the record of each applicant, first by the staff, then by the Board of Direction, constitutes a system of checks and balances that adds to the high value of membership in the Society. It is significant that Corporate Membership in this body constitutes a qualification for practice in the profession; is generally accepted in lieu of examination by state boards of engineering examiners for license to practice; and by itself usually qualifies an engineer as an expert witness in court actions.

Society Appointees

C. W. KUTZ, M. Am. Soc. C.E., has been appointed a member of the Committee on Flood Protection Data. The other members of this committee are GERARD H. MATTHES, chairman, FREDERICK H. FOWLER, ROBERT E. HORTON, IVAN E. HOUK, CHARLES W. SHERMAN, and DANIEL C. WALSER, all Members Am. Soc. C.E.

JULIUS ADLER, W. H. CONNELL, C. D. CURTISS, A. W. DEAN, GEORGE E. HAMLIN, E. W. JAMES, A. N. JOHNSON, JOHN A. MILLER, P. M. TEBBS, J. C. TRACY, and SIDNEY J. WILLIAMS, Members Am. Soc. C.E., and M. O. ELDRIDGE, Assoc. M. Am. Soc. C.E., represented the Society at the National Conference on Street and Highway Safety held in Washington, D.C., May 23–25, 1934.

LESLIE G. HOLLERAN, M. Am. Soc. C.E., has accepted an appointment as Society representative on the Coordination Committee of the Engineering Societies to fill the vacancy caused by the death of W. S. LEE, M. Am. Soc. C.E.

Preview of Proceedings

In the September issue of PROCEEDINGS, *the subject of uplift and seepage under dams commands the center of the stage, since the two main papers deal with it as related specifically to masonry dams on earth foundations. In both cases the subject is handled by acknowledged authorities in this field. Although the two papers proceed along more or less parallel lines of reasoning, the point of view and the angle of attack are in each case essentially different. Discussions on each paper will be separate.*

Security from Under Seepage—Masonry Dams on Earth Foundations

THE PAPER on "Security from Under Seepage—Masonry Dams on Earth Foundations," by E. W. Lane, M. Am. Soc. C.E., is based on the study and analysis of a large number of structures. The original report containing detailed information has been filed for reference and for the convenience of research scholars in the Engineering Societies Library in New York, N.Y. Furthermore, to enable those who do not have ready access to the facilities of the Society to study the more complete data, the Committee on Publications has arranged to distribute a limited number of sets containing photographic reprints showing details of the dams mentioned in the paper. The cost will be nominal and sufficient only to reimburse the Society for its outlay.

According to Mr. Lane, the ordinary method of analyzing a masonry dam on an earth foundation to make it safe against under seepage is faulty. It does not consider the fact that there is greater probability of percolation along level or slightly sloping contacts between the dam and its foundation than along vertical or steeply sloping contacts. It is claimed that the flow-depth and the electrical analogy methods are faulty in that they neglect the lesser resistance along the line of contact of a dam with its foundation as compared with that directly through the foundation material.

Seepage or "piping" can occur in two distinct ways: by flow along the line of contact of the structure and its foundation, or by flow directly through the foundation material. Flow ordinarily occurs along both these paths in inverse proportion to their relative distances. The probability of failure from the first of these causes can be analyzed rather well by experimental methods, but the second must be investigated largely by an analysis of the action of actual dams.

By studying the records of more than two hundred dams on earth foundations, Mr. Lane found that creep along contact surfaces which were horizontal, or nearly horizontal, should be assumed to offer only one-third as much resistance to piping as those with a slope of 45 deg or more. Analysis on this basis he terms "the weighted-creep" analysis. The "weighted-creep" distance of a cross section of a dam is given as the sum of the vertical creep distances plus one-third of the sum of the horizontal creep distances, and the weighted creep-head ratio is the weighted creep divided by the effective head. The paper gives a recommended schedule of safe weighted creep-head ratios for use in the design of major structures. Furthermore, it contains a wealth of good advice based on reasoning from the data available and on the valuable experience of the author.

Uplift and Seepage Under Dams on Sand

IN THE SECOND paper on this subject, "Uplift and Seepage Under Dams on Sand," L. F. Harza, M. Am. Soc. C.E., arrives at substantially the same conclusions as Mr. Lane, but from a different viewpoint. His paper presents some analytical methods which relate to familiar types of foundations, and describes graphical and electric analogy methods of general application. Thus Mr. Harza indicates how to determine the theoretical laws governing: (1) the hydrostatic pressure along the foundation contact; (2) the hydraulic gradient with which the water escapes upward at the toe of a dam; and (3) the approximate leakage under the structure. He offers these arguments as scientific nuclei around which to build further experimental data and field observations. His presentation of this subject is unique and valuable, dealing as it does with equipment that can be duplicated anywhere at moderate cost.

His detailed analysis includes a number of cases commonly found in practice, as for example: (1) the dam with heel sheeting but no toe sheeting; (2) the dam with toe sheeting but with heel apron in lieu of heel sheeting; (3) the dam with both heel and toe sheeting; and (4) the dam with single diaphragm of sheet piling. Another valuable aspect of this paper lies in its clarification of current definitions in this field which are often confused. Mr. Harza describes the significance of the "line-of-creep" and the "short-path" theory, and he completes his paper with a thorough description of the application of escaped gradients in design problems. The paper is well illustrated and should be found useful and interesting to a great number of engineers who are active in this field.

Third Paper to Appear in "Civil Engineering"

It has been planned for some time that, before the publication of these two papers in PROCEEDINGS, a prior but companion paper would be published in CIVIL ENGINEERING, that entitled "The Flow Net and the Electric Analogy," by E. W. Lane, M. Am. Soc. C.E., F. B. Campbell, Jun. Am. Soc. C.E., and W. H. Price. The importance of here referring to this third paper lies in the fact that Mr. Harza's paper pertains to the hydraulic-electric analogy. In it he states, "The writer's acquaintance with this principle was obtained from E. W. Lane." It was therefore planned that the publication of the paper by Messrs. Lane, Campbell, and Price should have anteceded the others, but it had to be deferred until the October number of CIVIL ENGINEERING owing to the necessity of devoting the September issue to abstracts of the papers presented at the Annual Convention in Vancouver. Otherwise, readers of Mr. Harza's paper could have first familiarized themselves with the fundamentals introduced by Mr. Lane.

News of Local Sections

Colorado Section

The Colorado Section reports that the following officers have been elected for the ensuing year: R. J. Tipton, President; F. C. Carstarphen, Vice-President; and E. B. Debler, Secretary-Treasurer.

Los Angeles Section

The annual field day and smoker of the Los Angeles Section were held on June 30 at the Altadena Golf Club, where all the facilities of the club house and grounds for sports and recreation had been reserved for the occasion. Following dinner, a series of vaudeville skits was presented, the climax of this part of the program being a display of magician's tricks. In all there were 91 present. A special meeting of the Section was called at the University Club on July 30 in honor of George T. Seabury, Secretary of the Society. On this occasion a talk was given by Ralph J. Reed, Director, who summarized the accomplishments of the meeting of the Board of Direction at the time of the Annual Convention. Mr. Seabury, then spoke on the current activities of the Society and other topics, including the present economic situation in the engineering world.

Louisiana Section

There were 48 members and guests present at a meeting of the Louisiana Section held in New Orleans on June 6. After a routine business session Allan T. Dusenbury, consulting engineer of New Orleans, gave an interesting talk on the employment of engineers of the state on survey projects under the auspices of the CWA. The feature of the occasion was the presentation of a technical paper by A. M. Fromherz, general contractor of New Orleans, which elicited enthusiastic discussion. The annual election of officers, which was held at this session, resulted as follows: John O'Neill, President; F. P. Hamilton, First Vice-President; Clifford H. Stem, Second Vice-President; H. A. Sawyer, Secretary; and R. L. Moroney, Treasurer.

Metropolitan Section

On Wednesday evening, August 8, probably the largest audience ever assembled in the Engineering Societies Building in New York, N.Y., listened to Admiral Joseph M. Reeves, Commander-in-Chief of the United States Fleet. This meeting was under the joint sponsorship of the Metropolitan Sections of the four Founder Societies, the Society of Naval Architects and Marine Engineers, the American Society of Heating and Ventilating Engineers, the Society of Terminal Engineers, and the Society of American Military Engineers. Admiral Reeves explained the purposes of the Navy and described the various classes of war craft and their tactical uses. A number of interesting motion picture films of the Navy were shown. Rear-Admiral R. E. Bakenhus, President of the New York City Post of the Society of American Military Engineers, presided. The attendance was about 1,100, and a large number were turned away.

Northwestern Section

At a meeting of the Northwestern Section, held at the University of Minnesota in Minneapolis on May 9, J. W. Shuman, of the Power Engineering Company, addressed the group on "Long-Range Weather Forecasting and Weather Cycles." Then Henry E. Riggs, Director of the Society, discussed the current activities of the Society. On May 31 a special technical meeting of the Section was held jointly with a session of local branches of other national engineering societies for the purpose of discussing the technical features of the "Zephyr," the new streamlined train, which was recently exhibited in Minneapolis. The principal speakers were Ernest Weber, superintendent of the American Motive Equipment Company, and J. E. Gardner, an electrical engineer for the Burlington Railroad. The discussion was followed by an inspection of the train. There were about 150 present at this session.

Portland (Ore.) Section

On May 19 a joint meeting of the Portland (Ore.) Section and the Oregon State College Student Chapter was held at Corvallis. The members enjoyed a field-day program held under the auspices of the Northwest Association of Highway Engineers. There were 52 present at the business and technical meeting of the Section, which was called to order at 5:30 p.m. At this session E. H. Collins, president of the Spokane Section, gave a brief talk. At 7:30 the members of the three organizations represented attended a banquet, which was followed by a program of entertainment furnished by the city of Lebanon, Ore.

On July 17 a dinner meeting of the Portland (Ore.) Section was held in honor of Society officers en route to their homes after attending the Annual Convention at Vancouver, B.C. The visitors were introduced by J. C. Stevens, Director of the Society, who served as toastmaster. A short, impromptu talk was given by President Eddy, and Secretary Seabury described some of the recent activities of the Society. There were 75 in attendance.

San Diego Section

The annual "Ladies' Night" of the San Diego Section was celebrated at the Churchill Hotel on May 24. Following dinner, H. W. Readen, of the Zellerbach Paper Company, gave an interesting talk on "The Romance of Paper," in which he presented a résumé of its history and uses from ancient Chinese days down to the present. The meeting was also a surprise birthday party in honor of Charles Edwin Grafton, who has been a Member of the Society since 1896.

A special meeting of the San Diego Section was called on July 31 in honor of George T. Seabury, Secretary of the Society, who spoke on some of the high lights of Society activities. He also commented on the unemployment situation in the engineering field and described the various engineers' codes.

San Francisco Section

There were 126 members and guests of the San Francisco Section present at its 175th regular meeting held at the Engineers' Club on June 19. During the business session several committee reports were read, and various matters of interest were discussed. It was voted that a resolution of sympathy on the death of the late Carl E. Grunsky, Past-President of the Society, be sent to his family. The speaker of the evening was Boris A. Bakhmeteff, whose topic was "Some Historical Aspects of Industrial Development and Engineering in Russia."

St. Louis Section

There were 31 members and guests in attendance at a meeting of the St. Louis Section held at the Mayfair Hotel on May 28. After various business matters had been discussed, the speaker of the occasion, J. W. Porter, a former member of the Missouri Public Service Commission, was introduced. He gave a very enlightening talk on the broad functions of the commission.

Virginia Section

An all-day meeting of the Virginia Section was held at the Country Club of Virginia in Richmond on June 29. The morning session was devoted to a discussion of business matters. An enjoyable luncheon was followed by interesting talks by James A. Anderson, State Engineer for the Federal Emergency Administration of Public Works, and Allen J. Saville. During the afternoon three inspection trips were made to local points of engineering interest. Special arrangements had been made for the ladies to view the city parks, and the Country Club provided facilities for golf and bridge for those who did not care to make any of the trips.

Student Chapter News

Tulane University

On March 17 the Tulane University Student Chapter made an inspection trip to the site of the Huey P. Long Bridge, at present under construction, above New Orleans. The party, numbering about twenty, saw many interesting aspects of the process of construction. On another occasion the members were privileged to hear A. E. Crockett, of the Jones and Laughlin Steel Company, of Pittsburgh, who gave a talk on the various stages in the manufacture of steel.

University of Nebraska

The University of Nebraska Student Chapter contributed to the success of the 1934 Engineers' Week, an annual affair sponsored by the various departments of the College of Engineering at the university. The Chapter had spent several months arranging interesting exhibits, which were displayed to the public on May 3 in an open house, one of the features of this week. The exhibits depicted various phases of the work done in the civil engineering courses during the past year. The week's activities were concluded with a banquet, which was largely attended.

Members of the University of Nebraska Student Chapter

University of Pittsburgh

On April 5 the University of Pittsburgh Student Chapter had the privilege of hearing L. H. Mitchell, Assistant Director of Economics of the U. S. Bureau of Reclamation, who gave an interesting, illustrated talk on the Boulder Dam project. Other meetings of the Chapter held during April were addressed by senior members.

ITEMS OF INTEREST

Engineering Events in Brief

Civil Engineering for October

This year marks the fiftieth anniversary of the skyscraper. The Home Insurance Building, started in 1884 in Chicago and recently wrecked, has been established by a qualified committee to be the world's first skyscraper. In it the late Major William LeBaron Jenney made use of a skeleton structural frame to support the building loads instead of following the practice in that day of carrying the loads to the foundations through the masonry walls themselves. In an article being prepared for the October number, Robins Fleming traces the background of development which culminated in Major Jenney's historic accomplishment, the forerunner of the modern thousand-foot tower building.

Now that attention is being directed to the building of a highway to Alaska and one to South America, engineers will find especial interest in the article by R. M. Strohl, M. Am. Soc. C.E. In 1928 a North Carolina contractor sent him to Costa Rica to build three government roads radiating from San José, the capital of the Republic. As far as possible the alignment of the existing century-old Telford-type roads built for ox carts was retained, but steep grades not readily negotiable by motors were revised by making deep cuts or by relocation. One of the routes selected is likely to form a link in the proposed Pan-American Highway.

A helpful analysis of court rulings relating to highway traffic, made by L. F. Rader, Assoc. M. Am. Soc. C.E., is also scheduled for October. When automobile meets automobile or pedestrian on the highway each must respect the rights of the other. In Mr. Rader's article the traffic engineer may find the legal effect of signs and signals set at intersections for the direction of traffic. Strange as it may seem, a person may be found guilty of contributory negligence in case of an accident even though he was obeying traffic regulations. In his article, Mr. Rader explains this and many other illuminating court decisions.

Also in the October number, Clarence T. Johnson, M. Am. Soc. C.E., will explain what are the ideal requirements for a surveying camp from a pedagogical and practical standpoint, and how a search for this ideal by authorities of the University of Michigan led to the selection of a site in Hoback Valley, Wyoming. This university has had a field surveying camp for the summer training of engineering students for over half a century, but formerly it was located near the campus. The success of the Wyoming camp during the past five years led Professor Johnson to set forth the experience of his department for the benefit of others faced with a similar problem.

How the Mexican Government solved the problem of controlling the Lerma River will be explained by H. E. M. Stevenson, Jun. Am. Soc. C.E., Construction Engineer on the work. During each rainy season floods threatened the Acambaro district, southwest of Mexico City, one of the most thickly populated and richest agricultural regions in the Republic. A dam 125 ft high, forming a reservoir of over 400,000-cu ft capacity, was built near Tepuxtepec. It was originally planned as a concrete gravity-type structure, but a geological study of the region dictated a change to a steep sloped rock-fill construction with a deep cut-off at the upstream toe of the fill tied into a flexible concrete slab anchored into and covering the upstream face.

Another paper for the October number, "The Flow Net and the Electric Analogy," by E. W. Lane, M. Am. Soc. C.E., F. B. Campbell, Jun. Am. Soc. C.E., and W. H. Price, engineers of the U. S. Bureau of Reclamation, is especially timely, because of the pioneer work being done in introducing these hydraulic tools into America. The flow net is described as a graphic device for picturing the accelerating passage of water, from which velocity, head, and pressure may be derived. The electric analogy, on the other hand, utilizes a rather simple laboratory apparatus, essentially a shallow pan containing a liquid conductor and fitted with electrical connections, sliding contacts, and ear phones. The passage of current through the liquid at varying voltage losses resembles the percolation of water through soil, as under a dam, at corresponding pressure losses. This article is in reality a forerunner of two papers in the September Proceedings on the subjects of seepage and uplift under dams.

Engineers as College Executives

In commercial fields and in large business enterprises the organizing ability of the engineer has long been recognized and utilized. Heads of great corporations, notably some of our most successful railroads, have frequently been drawn from the engineering profession.

In the academic field, however, this popularity has not been so pronounced, at least in years gone by. When it came to the choice of a college president the classic scholar and the clergyman seemed to be most in demand. But now there are indications of a change which tends to emphasize those qualities of organization and leadership which have distinguished the engineer from his fellows.

In the case of technical schools such as Rensselaer Polytechnic Institute, the Case School of Applied Science, and Lehigh University, engineer presidents have been the general rule for many years. Going beyond this field of technical education, the same tendency is now evident in universities of more general scope. Examples are found in Antioch College, with Arthur E. Morgan; in the University of Toledo, with Philip C. Nash; in the University of Maine, with Harold S. Boardman; and, during the present spring, in the installation of James A. Newcomb at the University of Virginia and Arthur C. Willard at the University of Illinois. It may be noted that Messrs. Boardman, Morgan, Nash, and Newcomb are Members of the Society.

Additional Engineers Honored

In the July issue of Civil Engineering was published an item listing members of the Society who were awarded honorary degrees during the 1934 commencement season. Since the publication of this list, information regarding other members similarly honored has reached Society Headquarters, as follows:

Hugh L. Cooper, M. Am. Soc. C.E., Doctor of Engineering, Rensselaer Polytechnic Institute.

Hardy Cross, M. Am. Soc. C.E., Doctor of Science, Hampden-Sydney College.

Frank E. Weymouth, M. Am. Soc. C.E., Doctor of Engineering, University of Maine.

Popularizing Soil Research

Publicity for technical accomplishments—particularly the more spectacular varieties, such as the construction of great dams and bridges—is becoming more and more frequent. Not so often, however, is research in the realm of civil engineering brought to the attention of the general public.

An exception to this fact is noted in the Sunday, August 12, issue of the *New York Herald Tribune*, in which an interesting story centers about the work of the Society's Committee on Earths and Foundations. Much of the article has to do with the settlement of famous structures, such as St. Paul's Cathedral in London, the Leaning Tower of Pisa, and the Washington Monument. These news items are tied in, however, with the work of the committee because they emphasize the fact that soil research may solve specific problems and prevent similar difficulties in the future.

The work of the Committee on Earths and Foundations, under the chairmanship of Lazarus White, M. Am. Soc. C.E., is receiving material financial assistance through the Engineering Foundation. A number of reports from the committee have been issued. The most recent appeared in the May 1933 issue of Proceedings and has been supplemented by generous written discussion in the intervening months.

Old Y-Bridge at Zanesville, Ohio

By WILBUR J. WATSON, M. AM. SOC. C.E.
ARCHITECT AND ENGINEER, CLEVELAND, OHIO

AT THE FOOT of Main Street, in Zanesville, Ohio, a timber bridge was built across the Muskingum River in 1814. It was so frail and full of faults that it fell into the river in 1818. The same year it was replaced by a somewhat better and stronger wooden bridge, which carried traffic until about 1832, when it too collapsed into the water. This bridge, in turn, was succeeded by a more ambitious structure built in the shape of a "Y." Although this shape was certainly unusual for that day, it finds a counterpart in the plans for the proposed Triborough Bridge over the East River in New York.

Over this structure the traveler could cross the Licking or the Muskingum River without crossing both, or by taking the east and the west arms of the bridge could cross both rivers at once. The bridge was located on the line of the old National Road, now U. S. Route 40, at the point where the surveyors of Zane's Trace ran their line in 1796. The very best of timber went into this third bridge, which was considered to be a marvel for its time, both in design and construction. Like other timber crossings of its day it was roofed over.

It is not certain who the builders of the bridge were, but it is said that one of them, Ebenezer Buckingame was drowned in 1832 while superintending its construction. All three arms of the bridge were built by private capital and were toll structures. In 1868 the State Legislature authorized the purchase of the main parts of the Y-bridge, and the county bought the West Zanesville arm, whereupon the bridge became free. The remuneration is said to have been approximately $28,000.

At the intersection of the three arms of the bridge was located the toll house, over the large circular pier. Under modern traffic conditions an officer would have been needed to direct the flow around this "traffic circle" in the middle of the bridge. However, this unique Y-bridge at Zanesvlle was replaced in 1900 by a concrete structure more adapted to the requirements of modern highway transportation.

NEWS OF ENGINEERS

From Correspondence and Society Files

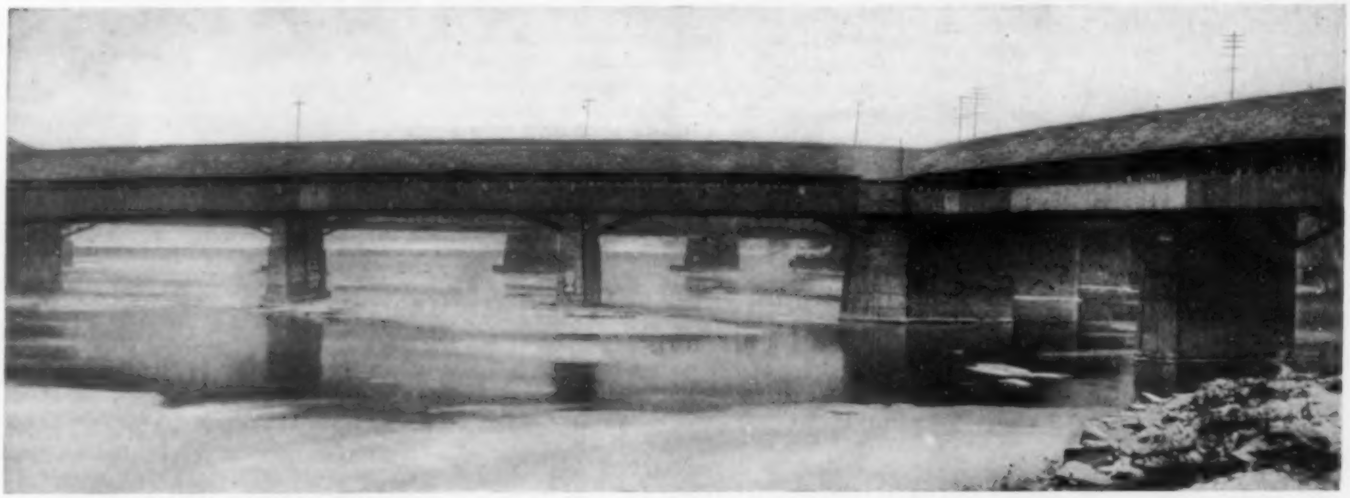
ABRAM SIEGEL is now assistant chief draftsman for the U. S. Forest Service, with headquarters in Winchester, Ky.

CECIL E. PEARCE, for the past six years chief designing engineer of the Pasadena Water Department, has recently accepted a connection in the Division of Dam Design of the U. S. Bureau of Reclamation in Denver, Colo.

P. N. GIBBINGS, JR., has taken an engineering position with the Tidewater Construction Corporation, of Conway, S.C.

CHIA Y. HOU, formerly director of the Department of Public Works of Nanking Municipality, Nanking, China, is now associate managing director and associate engineer-in-chief of the Chekiang-Kiangsi Railway. His headquarters are in Hangchow, China.

D. A. DEDEL has resigned as designing engineer for the Ambursen Construction Company, of New York, N.Y., to accept a



TIMBER Y-BRIDGE AT ZANESVILLE, OHIO, BUILT IN 1832 AND REPLACED IN 1900

position with the U. S. Bureau of Reclamation in Denver, Colo.

Alfred T. Waidelich has sailed for Istanbul, Turkey, where he will be an instructor in civil engineering at Robert College.

Carey H. Brown recently resigned as chairman of the Technical Board of Review of the Public Works Administration, in Washington, D.C., to accept a connection with the Eastman Kodak Company, of Rochester, N.Y., in the capacity of superintendent of engineering and maintenance.

Leonard Grime is at present connected with National Silicates, Ltd., of New Toronto, Ontario. He was formerly a draftsman for the Standard Steel Construction Company, Ltd., of the same city.

Donald D. Price, formerly district engineer for the Portland Cement Association, of Lincoln, Nebr., has accepted a connection with the Platte Valley Public Power and Irrigation District in the capacity of chief engineer and general manager. His headquarters are North Platte, Nebr.

Paul D. Sargent, in association with Harry E. Cotton and M. J. Adams, has opened an office in the Statler Building in Boston, Mass., for the purpose of promoting a market for corrugated metal pipe culverts and drainage structures. All were formerly employed by the New England Metal Culvert Company.

William Pitcher Creager has established a hydraulic engineering practice in the Electric Building in Buffalo, N.Y. He was formerly chief engineer of the Buffalo office of the Power Corporation of New York.

Dana M. Wood is now a senior hydraulic engineer for the Tennessee Valley Authority, with headquarters in Knoxville, Tenn.

J. G. Conrath has now joined the staff of the Pennsylvania Railroad on an electrification project under the auspices of the Public Works Administration. His office is in East Orange, N.J.

James G. Jobes was recently transferred from the U. S. Waterways Experiment Station at Vicksburg, Miss., to the U. S. Engineer Office at Zanesville, Ohio, where he has the rank of associate engineer.

Dean G. Edwards is now deputy administrator for the NRA in charge of the Apparels Section, with headquarters in Washington, D.C. He was formerly chief engineer of the Civil Works Administration of New York, N.Y.

Harry L. Thompson has resigned as draftsman for the Middle Rio Grande Conservancy District to accept a connection with the U. S. Bureau of Reclamation in Denver, Colo.

Franklin Rogers, formerly traveling representative for the District Engineer of the 8th District under the CWA, is now with the National Park Board of the U. S. Department of the Interior, with offices in San Francisco, Calif.

C. W. Ullom was recently appointed appraisal engineer for the Muskingum Watershed Conservancy District, of New Philadelphia, Ohio. He was formerly field engineer for the Dayton Morgan Engineering Company, of Springfield, Ohio.

John T. Howell is now a junior designing engineer for the U. S. Bureau of Reclamation, in Denver, Colo. He was formerly with the Pacific Gas and Electric Company, of Oakland, Calif.

Changes in Membership Grades

Additions, Transfers, Reinstatements, Deaths, and Resignations

From July 10 to August 9, 1934, Inclusive

Additions to Membership

Beach, George Oliver (Jun. '34), 507 Sixteenth St., Sioux City, Iowa.

Beebe, Harold DeForest (Jun. '34), 45 Willow Ave., Plainfield, N.J.

Berry, William Elmo (Assoc. M. '34), County Engr., 510 Court House, Tacoma, Wash.

Bespalow, Eugene Frederick (Assoc. M. '34), Cons. Engr., Tri-State Culvert Mfg. Co.; Engr. and Mgr., Hollywood Concrete Pipe Co.; Sales Engr., Choctow Culvert and Machinery Co. (subsidiaries), 491 South 2d St., Memphis, Tenn.

Blair, John Cambelton (Jun. '34), Care, State Reclamation Dept., Austin, Tex.

Brown, James Lester (Assoc. M. '34), Office Engr., El Vado Dam, Middle Rio Grande Conservancy Dist., Chama, N.Mex.

Chapman, Lauren Bock (Assoc. M. '34), Wrightwood, Calif.

Chettle, Earl Vincent (Jun. '34), City Engr. (Res., 102 North 1st East), Brigham City, Utah.

Eberle, Rudolph Eugene (Jun. '34), R. F. D. 1, Emporia, Kans.

Garnell, Alfred William (Jun. '34), Box 1491, Denver, Colo.

Goldstein, Joseph (Assoc. M. '34), Insp., Dept. of Docks, New York City (Res., 713 East 175th St.), New York, N.Y.

Halpin, Frank Cornelius (Jun. '34), Draftsman, The Texas Co.; 1195 North St., Beaumont, Tex.

Harvey, Linval Dallas (Jun. '34), Lees River Ave., Swansea, Mass.

Harvey, Marvin Spears (Assoc. M. '34), 725 Audubon Boulevard, Jackson, Mich.

Jenks, Robert Jeremiah (Jun. '34), Engr. Dept., Washington Water Power Co. (Res., Brunot Hall Apartment, Apartment Y), Spokane, Wash.

Johnston, Bruce Gilbert (Jun. '34), Care, Dept. of Civ. Eng., Columbia Univ., New York, N.Y.

Kelly, Henry Jervey (Assoc. M. '34), Asst. Civ. Engr., Eng. Service Div., Tennessee Val. Authority, Knoxville, Tenn.

Koessner, Erwin (Jun. '34), R. F. D. No. 3, Box 230-E, Seattle, Wash.

Leeper, Laverne Davidson (Jun. '34), Designer, Oliver G. Bowen, Los Angeles (Res., 519 South Oakland St., Pasadena), Calif.

Lewis, William Whitfield (Jun. '34), Instr., Civ. Eng., Duke Univ., Durham, N.C.

Markiewicz, Victor Adam Xenon (Jun. '34), Topographical Draftsman, Dept. of Parks, City of New York (Res., 17 West 10th St.), New York, N.Y.

Morgan, Ellis Hamilton (Assoc. M. '34), Application Examiner, Tennessee Val. Authority (Res., 1823 Laurel Ave.), Knoxville, Tenn.

Newman, Rupe Beardon, Jr., (Assoc. M. '34), Res. Engr.-Insp., Federal Emergency Adminis tration of Public Works, Room 4, Post Office Bldg., Memphis, Tenn.

Nordeen, Carl Edward (Assoc. M. '34), Hydr. Engr., U. S. Geological Survey, Washington, D.C. (Res., 3954 Thirty-second St., Mount Rainier, Md.)

Silverman, Samuel Lelchuk (Jun. '33), 217 Church Ave., Brooklyn, N.Y.

Strohm, William Edward (Assoc. M. '34), Structural Designer, State Highway Dept. (Res., 570 1/2 East Garcia St.), Santa Fe, N. Mex.

Sutherland, Marvin McTyiere (Jun. '34), Care, U. S. Geological Survey, Spruce Pine, N.C. (Res., Prospect Ave., Pulaski, Va.)

Westcott, Clifford Harper (M. '34), Chf. Engr., Westcott Eng. Co., 205 West Wacker Drive, Room 1516, Chicago, Ill.

Will, Theodore Nielsen (Jun. '34), Engr. Asst., City of Saginaw (Res., 707 South Washington Ave.), Saginaw, Mich.

Wyman, Alton Bertram (Jun. '34), With Dist. Engr., State Civil Works Administration, Court House (Res., 2013 Baird Ave.), Portsmouth, Ohio.

TOTAL MEMBERSHIP AS OF AUGUST 9, 1934

Members	5,750
Associate Members	6,272
Corporate Members	12,022
Honorary Members	17
Juniors	3,144
Affiliates	105
Fellows	4
Total	15,292

Membership Transfers

Adams, Thomas Caldwell (Jun. '24; Assoc. M. '34), Associate Prof., Civ. Eng., Univ. of Utah; Special Representative in Chg. of Utah Control Surveys, U. S. Coast and Geodetic Survey (Res., 124 F St.), Salt Lake City, Utah.

Anderson, Victor Charles (Jun. '24; Assoc. M. '34), Pres., Capital Steel Co.; Structural Engr. (Anderson & Knoop), 329 Gazette Bldg., Little Rock, Ark.

BOSSY, REGINALD ARTHUR (Jun. '26; Assoc. M. '34), Res. Engr., State Highway Dept., Box 332, Floresville, Tex.

BOWDEN, EDMUND WARREN (Assoc. M. '26; M. '34), Asst. to Chf. Engr., The Port of New York Authority, 111 Eighth Ave., New York, N.Y. (Res., 648 Dorian Rd., Westfield, N.J.)

BUCHMUELLER, MILTON (Jun. '24; Assoc. M. '34), Civ. Engr., St. Louis Water Div. (Res., 5328 North Kingshighway Boulevard), St. Louis, Mo.

COKER, WILLIAM CALEB (Jun. '26; Assoc. M. '34), Agt. for Receivers, Peoples State Bank of South Carolina, 1530 Main St. (Res., 1728 College St.), Columbia, S.C.

DOUGHTY, SAMUEL CLIFFORD (Jun. '30; Assoc. M. '34), Asst. Engr., James Forgie, 15 William St., New York, N.Y.

FELD, JACOB (Jun. '22; Assoc. M. '24; M. '34), Cons. Engr., 103 Park Ave., Room 1116, New York, N.Y.

FULLER, RAYMOND STILES (Assoc. M. '22; M. '34), Engr. of Distrib., Dept. of Gas Constr. and Operation, Pacific Gas & Elec. Co., 80 El Camino Real, Berkeley, Calif.

GESSNER, EDWARD HEIM (Jun. '31; Assoc. M. '34), Field Engr., F. Shutts & Sons (Res., 119 Audubon Boulevard), New Orleans, La.

GIFFORD, LEROY DELAND (Assoc. M. '28; M. '34), Director of Research, California Taxpayers' Assoc., Subway Terminal Bldg. (Res., 1689 Kaweah Drive), Pasadena, Calif.

GILBOY, GLENNON (Jun. '27; Assoc. M. '34), Asst. Prof., Soil Mechanics, Mass. Inst. Tech., Cambridge, Mass.

GROOMS, ROY SEWELL (Jun. '27; Assoc. M. '34), Computer, State Highway Department, Box 71, Decatur, Ala.

HARRELL, CHARLES ADAIR (Assoc. M. '31; M. '34), City Mgr., City Hall, Binghamton, N.Y.

HARRISON, KENNETH JOSEPH (Assoc. M. '29; M. '34), Res. Engr., Los Angeles County Flood Control Dist., Los Angeles, Calif.

HAYES, NATHANIEL PERKINSON (Jun. '27; Assoc. M. '34), Sales Mgr., Carolina Steel & Iron Co. (Res., 311 North Tremont Drive), Greensboro, N.C.

HEIM, ARTHUR IRVING (Jun. '21; Assoc. M. '24; M. '34), Chf. Draftsman, A. E. Wheeler, 25 Broadway, New York, N.Y.

HENDERSON, PAUL FLEMING (Assoc. M. '27; M. '34), Project Engr., U. S. Indian Irrig. Service, Myton, Utah.

HOUGH, FLOYD WOODWORTH (Jun. '20; Assoc. M. '25; M. '34), Care, U. S. Coast and Geodetic Survey, Washington, D.C.

LAWTON, MILTON BURBANK (Jun. '27; Assoc. M. '34), Junior Engr., State Transit Comm., 270 Madison Ave., New York (Res., 81 Anderson Ave., Scarsdale), N.Y.

LEWIS, ISIDORE LEONARD (Assoc. M. '27; M. '34), Senior Draftsman, Dept. of City Transit (Res., 5543 Walnut St.), Philadelphia, Pa.

MILONE, MICHAEL EDWARD (Jun. '28; Assoc. M. '34), Asst. Engr., Board of Transportation, 250 Hudson St. (Res., 595 East 134th St.), New York, N.Y.

MIRABELLI, EUGENE (Assoc. M. '24; M. '34), Asst. Prof., Structural Eng., Mass. Inst. Tech., Cambridge, Mass.

OOTHOUT, RAYMOND MILTON (Jun. '28; Assoc. M. '34), Constr. Engr., Koss Constr. Co., 205 Old Colony Bldg., Des Moines, Iowa.

THOMPSON, PERCY EDWARD (Jun. '31; Assoc. M. '34), With Bridge Div., Los Angeles County Road Dept., Los Angeles (Res., 724 North Louise St., Glendale), Calif.

TOTH, ALEXANDER STEPHEN (Jun. '28; Assoc. M. '34), 3605 Third Ave., New York, N.Y.

TWICHELL, TRIGG (Jun. '26; Assoc. M. '34), Associate Engr., U. S. Geological Survey (Res. 3208 Harris Park Ave.), Austin, Tex.

VAN REEKUM, VERNON JOHN (Jun. '30; Assoc. M. '34), Civ. Engr., City of University Park (Res., 3418½ McFarlin Boulevard), Dallas, Tex.

RESIGNATIONS

BOSSEN, LESLIE EDWIN, Jun., resigned July 12, 1934.

BOYT, ELMER VERNON, Jun., resigned July 24, 1934.

CUFF, JAMES EDWARD, Assoc. M., resigned July 13, 1934.

GOULD, MAURICE AUGUSTUS, Assoc. M., resigned July 31, 1934.

HAWORTH, HAROLD LORENZ, Jun., resigned July 1, 1934.

JOHNSON, ROBERT KINNAIRD, Assoc. M., resigned July 31, 1934.

LANE, EDWIN GRANT, Assoc. M., resigned July 20, 1934.

LIBBY, HERMAN BREWER, M., resigned July 31, 1934.

RIDGE, WILLIAM CLENDENNING, Assoc. M., resigned July 12, 1934.

SMITH, GEORGE RUDOLPH, Jun., resigned July 30, 1934.

SOLAKIAN, ARSHAG GAZAR, Assoc. M., resigned July 9, 1934.

WILGUS, HERBERT SEDGWICK, M., resigned July 31, 1934.

DEATHS

BLAKE, HOWARD COLBURN. Elected M., May 28, 1923; died July 17, 1934.

EARLE, FRANK HASBROUCK. Elected Affiliate, Jan. 19, 1925; died Aug. 12, 1933.

HENGST, ROBERT GRAHAM. Elected Assoc. M., Oct. 7, 1903; M., May 5, 1908; died May 20, 1934.

JONES, PERCY FRANCIS. Elected Assoc. M., Feb. 4, 1914; M., Jan. 20, 1922; died Jan. 28, 1934.

KING, WARREN RAYMOND. Elected Assoc. M., July 9, 1923; died July 25, 1934.

NETLAND, LARS. Elected M., June 10, 1929; died July 6, 1934.

NOBLE, HARRY ALONZO. Elected M., Sept. 3, 1913; died June 14, 1934.

O'ROURKE, JOHN FRANCIS. Elected M., April 2, 1884; died July 28, 1934.

REDFERN, IRA TAYLOR. Elected Assoc. M., Jan. 15, 1923; died July 20, 1934.

STIERLIN, GUSTAVE ARNOLD. Elected M., Aug. 4, 1924; died May 16, 1934.

Men Available

These items are from information furnished by the Engineering Societies Employment Service, with offices in Chicago, New York, and San Francisco. The Service is available to all members of the contributing societies. A complete statement of the procedure, the location of offices, and the fee is to be found on page 85 of the 1934 Year Book of the Society. To expedite publication, notices should be sent direct to the Employment Service, 31 West 39th Street, New York, N.Y. Employers should address replies to the key number, care of the New York office, unless the word Chicago or San Francisco follows the key number, when the reply should be sent to the office designated.

CONSTRUCTION

CONSTRUCTION ENGINEER; Jun. Am. Soc. C.E., 31; married; Carnegie Institute; 3 years surveys, new railroad, highway, harbor; 4 years construction, new railroad, railroad and highway bridges, undergrade, overhead crossings, city viaducts, warehouses, harbor; 5 months superintendent, construction state highway bridge; estimator, cost reports, design; 2 years, estimate, design, erection, supervision manufactured reinforced concrete construction products. C-7370.

GRADUATE ENGINEER; Jun. Am. Soc. C.E.; 32; 2 years experience in construction, inspection, and design of highways and steel and reinforced concrete bridges; pavements; pipe lines; drain tiles; instrument experience. Testing materials, scales, and concrete beams; 1 year on surveys and topography; shipping clerk for 3 years. C-4630.

CIVIL ENGINEER; Jun. Am. Soc. C.E.; 31; married; Cornell University, A.B. and C.E. degrees; 10 years engineering and construction experience in United States and South America; experience includes construction of concrete and steel bridges, topographic mapping, railroad location and operation, cost accounting, statistics, reports; engineering supervision of large-scale excavations and open-cut mining operations. Excellent references. D-2252.

CIVIL ENGINEER; Jun. Am. Soc. C.E.; 32; 9 years experience with general contractors and engineers; estimating, drafting, surveying, and layout work; supervision of construction work in field; bridges, highways, and gasoline plants; present location, Oklahoma. D-3286.

CONSTRUCTION ENGINEER; Jun. Am. Soc. C.E.; 30; married; 10 years experience on construction of dams, hydro-electric plants, bridges, buildings, and pavements. Qualified to take responsible charge of any construction job as superintendent or chief inspector. Available immediately. Location immaterial. Excellent references. D-1962.

DESIGN

CIVIL AND STRUCTURAL ENGINEER; Jun. Am. Soc. C.E.; licensed professional engineer; 30; B.S. in C.E. and C.E. degrees; experienced as a designer, draftsman, checker, detailer, and estimator of structural steel and reinforced concrete structures. References and samples of work sent on request. C-6186.

STRUCTURAL AND MUNICIPAL ENGINEER; Assoc. M. Am. Soc. C.E.; graduate C.E.; 15 years experience. Experienced designer, estimator, and superintendent, principally of architectural engineering and sewage disposal. Competent to limited extent on mechanical installations, heating and refrigeration, pumps and conveying machinery. Also considerable heavy railroad design and movable bridges and cranes. Will go anywhere, including abroad. C-2701.

EXECUTIVE

DRAFTSMAN; Assoc. M. Am. Soc. C.E.; computer and surveyor in real estate development. Design, plan, and construction of necessary municipal improvements. Roads, water, gas, electric installations, sewer and subway construction. Grade separations (railroad and highway), preliminary surveys, general planning, estimating, and construction of bridges. Married; 44 years of age; licensed professional engineer in New York. D-2092.

PATENT ATTORNEY; Assoc. M. Am. Soc. C.E.; capable of organizing and managing patent department. University graduate. Professional engineering degree. Member of New York Bar. Registered U. S. and Canadian patent attorney. Broad business experience; 8 years patent experience with old, established patent law firm and patent department of large corporation. B-1819.